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THE LIFE-HISTORY OF A SOLAR ECLIPSE.

By E. Walter Maunder, *Sec. R.A.S., Superintendent of the Physical Department, Royal Observatory, Greenwich.*

SHORTLY before the recent total eclipse, a paragraph went the round of the papers to the effect that this eclipse would be a repetition of one which occurred some eight hundred and sixty years before our era, and which was made use of to bring about a revolution in the government of Assyria. Seeing, however, that an eclipse of the sun is caused simply by the three bodies—the sun, moon, and earth—coming into the same straight line, the moon being between the other two, it seems at first that it is absurd to speak of one eclipse being a recurrence or repetition of another, unless we go further, and regard every eclipse as a recurrence of any other, the same three bodies being alone concerned in each and all of them.

There is, however, a very real signification attaching to the expression. Certain eclipses do stand in a special relationship to each other, a relationship which they do not hold to the general run. Eclipses have their own special characteristics, and it is easy to see how these arise. The periods of the earth and moon are nearly, but not quite, commensurable, and the conditions which prevail at one eclipse are reproduced very closely, but not precisely, after a considerable interval of time.

To go more into detail. Since the orbit of the moon has a slight tilt, and does not coincide with the plane of the earth's orbit, it follows that, instead of having a solar and a lunar eclipse every month, an eclipse only takes place when the new or full moon falls near one or other of the nodes, the two points where the plane of the orbit of the moon intersects the plane of the orbit of the earth. Next, the time which the moon takes in moving from one of her nodes round to the same node again is not the same as that which she takes in travelling from conjunction to conjunction, that is, from new moon to new moon again. Or, to use the technical terms, a "draconic" month is not the same as the "synodic." The synodic month, or lunation, the "month" in the ordinary sense of the word, is 29 days 12 hours 44 minutes; the draconic month, the return to the node, is accomplished in 27 days 5 hours 6 minutes, or two days and nearly eight hours sooner. If we have a total solar eclipse at one new moon, the moon being in conjunction and at her node at the same moment, then when she reaches the same node the next month she will still be $2\frac{1}{3}$ days from "new," and when "new" will have passed her node by about 30°. Thus in Fig. 1, M represents the moon as new exactly at the node, and therefore as centrally eclipsing the sun. When she is new the following month she will be at M_2, and as the figure illustrates the descending node, will be below the sun, S_2, as seen from the earth at conjunction. No eclipse can therefore take place; indeed, if the moon has passed her node by as much as 17° she will in general escape eclipse, and under special circumstances a distance of even $15\frac{1}{2}$° may leave her clear of the sun.

The next month will see the moon about 60° from her node when "new"; another month the distance will be not quite 90°. The conditions for an eclipse are, therefore, more unfavourable than ever. But in six months' time, when the distance from the first node is a little less than 180°, the moon is necessarily near the opposite node, and an eclipse follows. Then for six months more there is no eclipse, until, at the end of twelve months, we find that once again conjunction occurs nearly at the node. Twelve times the synodic month is 354 days 8 hours 48 minutes 34 seconds, or not quite fifteen hours longer than thirteen times the draconic month, 353 days 18 hours 12 minutes 48 seconds, and the moon is only about 8° from the node at the "new." But since twelve lunar months equal 354 days, the new eclipse occurs eleven days earlier in the year than its predecessor; and since the mean limit for the distance from the node is 17°, it is

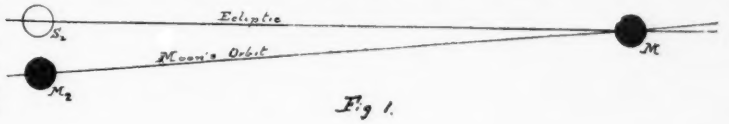

Fig 1.

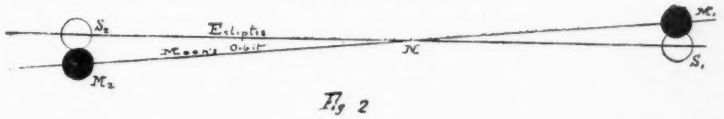

Fig 2

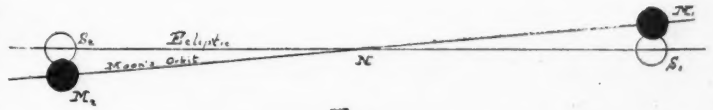

Fig 3

possible to have a set of five eclipses following each other in successive years, but each falling ten or eleven days earlier in the year than the preceding eclipse had done. The first of the five would be a very small partial eclipse, since it would be 16° or 17° from the node; the next would be a much larger eclipse, 8° from the node; the third would be central, and the fourth and fifth would correspond to the second and first respectively. The following little table gives the most recent example of the kind:—

	Date.	Greenwich Civil Time. d.	h.	Least distance of centre of earth from centre of shadow.	Character of Eclipse.	Greatest Phase.
1884.	March	27	7	1·46	Partial	0·149
1885.	March	16	18	0·80	Annular	——
1886.	March	5	22	0·10	Annular	——
1887.	February	22	21	0·60	Annular	——
1888.	February	11	23	1·27	Partial	0·506

A set of five is, however, of comparatively infrequent occurrence; the usual number is four.

There is another and much closer correspondence between the draconic and synodic months than that supplied by thirteen of the former to twelve of the latter. For 223 ordinary or synodic months amount to 6585 days 7 hours 42 minutes 39 seconds, whilst 242 returns to the node require 6585 days 8 hours 35 minutes 12 seconds. The difference between the two is less than an hour; only $52\frac{1}{2}$ minutes in fact. If then the moon is sufficiently near its node at a given conjunction to cause an eclipse, then in $6585\frac{1}{3}$ days, say 18 years and 11 days, the same conditions will be almost exactly reproduced, and another eclipse will, in general, take place.

This period of 223 months, or a little over 18 years, is the period of the *Saros*, the great astronomical cycle handed down to us from remotest antiquity by the Chaldæan astronomers. And it is the almost perfect reproduction, after the interval of $6585\frac{1}{3}$ days, of the conditions of the earlier eclipse, which has led astronomers to connect the two eclipses together, and to speak of the later one as the recurrence or repetition of the former.

This reproduction of the conditions of the earlier eclipse is even more perfect than we have stated. Not only is it the case that the moon, when in the same position relative to the node, has only passed conjunction by an hour, but in four hours and a half she will come into exactly the same position relatively to her perigee as she occupied at the first eclipse. For besides the synodic and the draconic months, of which we have already spoken, there are yet others, one of the most important of which is the "anomalistic" month—the time, that is, that the moon takes to pass from her point of nearest approach to the earth round to the point of nearest approach again. The significance of this fact is two-fold. First, the moon is almost precisely at the same distance from the earth as she was at the earlier eclipse; she therefore appears to be of the same angular diameter as before. Next, as the moon moves at a varying speed in her orbit, a speed varying with her distance from the earth, and therefore on her distance from her perigee, it follows that her rate of motion is almost exactly the same as before. When we take into consideration that the *Saros* is only eleven days longer than a complete number of years, we see that the earth also must be not very far from the point of her orbit that she occupied before, so that her distance from the sun, the apparent diameter of the latter, and the earth's rate of motion in her orbit, are but little different from what they were before. The *Saros*, therefore, represents a very close approach to commensurability of the solar year, and the synodic, anomalistic, and draconic months; and reproduces almost precisely the relation of the moon to the node of its orbit, and to conjunction with the sun, the apparent diameters of the sun and moon, and their apparent rates of motion in the heavens. It is a singularly close approximation to a perfect cycle.

And there is a yet further correspondence between the eclipses which follow each other at the *Saros* interval. Not only does the second eclipse occur almost exactly in the same position with regard to the node as the first, and in the same position with regard to the lunar perigee; not only are sun and moon of nearly the same apparent diameter at the one occurrence as they were at the previous one; not only are their rates of apparent motion nearly the same, but the track of the shadow cast by the moon on the earth lies almost in the same latitude. For as the *Saros* is only eleven days longer than a complete number of years, the position of the earth's axis with regard to the sun is very nearly the same. The sun is in the zenith over very nearly the same latitude as it was before; or, if we look at it from a different standpoint, the apparent centre of the earth's disc, as seen from the sun, has nearly the same latitude as on the earlier occasion. But it has not the same longitude, for the period of the *Saros* being 6585 days and nearly 8 hours, the earth would have exceeded an integral number of rotations by nearly a third; or, since the earth rotates from west to east, the longitude of the centre of the disc would be nearly 120° further west. Three *Saroses* would, however, bring us very nearly to an integral number of days, and the position in longitude would be pretty nearly reproduced, whilst the position in latitude would have not greatly changed. Some writers on astronomy have therefore thought that the original Chaldæan period was not 18 years, but 54 years, as with the limited means of communication in the ancient world it must have often been impossible for astronomers to have known by observation of the occurrence of the eclipses falling 18 and 36 years after a given one, whilst that falling 54 years later would reproduce its conditions pretty faithfully. However this may have been, the knowledge of the actual *Saros* of 18 years 11 days clearly goes back to great antiquity, though whether it was first arrived at from observation or from induction we cannot now decide.

This shift in terrestrial longitude of 120° has its point of interest; for the average length of the shadow track in an eclipse is about 130°, moving from west to east, from the point where the sun rises just as the eclipse is over, to that where the sun sets just as it is beginning. It follows, therefore, that the shadow track in a given eclipse ends very nearly in the same longitude as its predecessor began, and begins very nearly in the same longitude as its successor will end. The tracks of three successive eclipses, therefore, together nearly belt the globe; not in a circle, however, but in a gentle spiral, a spiral continued in the eclipses which follow.

It is no wonder, then, that by a very natural and permissible idealization the eclipses following each other at the interval of a *Saros* have been considered to be the same, and their successive returns chronicled in relation to each other, just as we might record the successive appearances of a short period comet.

If we regard, then, the successive eclipses following each other at the *Saros* interval as constituting one single entity, we shall soon see that an eclipse—using the word in this wider sense—has a very definite history. It has its birth, infancy, full vigour, old age and death. For slight and insignificant as is the failure of the *Saros* to precisely harmonize the different months and the year together, the outstanding differences—the hour late in reaching the node, the five hours and a half late in reaching perigee, the 10° difference in the solar longitude—all

combine to make the eclipse at one return a little different from what it was the time before. And since these differences continually increase, there is a steady and progressive change in the character of the eclipse.

To take one point alone—the fact that the moon arrives at conjunction about an hour sooner than she arrives at the node. The maximum distance from the node at which an eclipse can take place is 18°; 18° on either side of the node gives a range of 36°, or one-tenth of the circle, for the extent of the region wherein an eclipse is possible. One-tenth of 27 days 5 hours is 65 hours. If the lagging in the return to the node were exactly an hour, we should then have the life-time of an eclipse extending to 65 or 66 returns; as it is, it is a little longer than this, and like the life-time of man himself it reaches three-score and ten, sometimes a little more, but no eclipse "by reason of strength" can attain to four-score returns. The usual duration is seventy or seventy-one,* and curiously enough the total number of eclipses in a particular *Saros* is also seventy or seventy-one; solar and lunar eclipses being both included. During this time the eclipse will have travelled down the year, eleven days at a time, twice and a little over; the last occurrence falling some thirty-six days later in the year than the first.

As has been already mentioned, an eclipse will generally take place if the moon when "new" is not more than 17° from the node. Let us suppose that a time comes in the history of a decaying eclipse when the moon is 13° from the node at conjunction, as in Fig. 2, where N represents the node, and S and M the positions of sun and moon at mid-eclipse. What will follow? At conjunction next month the moon will be some 30° further on in her orbit, and will be about 17° from the node on the other side, as at M_2, and in the general way we shall have a grazing eclipse. We shall have, therefore, two partial eclipses only a month apart. The next *Saros* will bring about a repetition of the same state of affairs, only that the earlier eclipse of the pair will take place further from the node, whilst the second eclipse, the new one, which had been a mere grazing eclipse at the previous *Saros*, would fall nearer the node, and hence will give a somewhat larger phase than before. This state of things is represented in Fig. 3, where the new eclipse at M_2 S_2 has manifestly more body than in Fig. 2. This process would be repeated several times, the old eclipse continually receding from the node and becoming smaller, the new one approaching it and growing larger, until at last the moon would have drifted too far from the node in the earlier month to cause an eclipse. Henceforward there would be only one eclipse, that of the later month. This would increase in phase time after time; would become annular or total; would at length fall close to the node; would pass it; and then, receding from it on the further side, would begin to diminish in phase. Lastly, as the seventy returns began to run out, a time would come when this eclipse would fall a full day or more before the node was reached. Then the next month we should have the moon at conjunction just near enough to the node to cause a very small partial eclipse, and once again a pair of eclipses would be formed. As before, the earlier eclipse would grow smaller and smaller, waning as the new eclipse waxed, and ere long it, too, would in its turn cease to exist, like the eclipse which it had superseded.

This is the law, then, of eclipse life. Each is born as the second member of a pair of eclipses; each dies as the first member of such a pair. The solar eclipse cycle is the true Phœnix of the ancients—the Arabian bird which sprang from the ashes of its dying parent, and which will, in like manner, give birth to its solitary offspring in its own dying moments. It lives for 1262 or 1280 years, forty generations of men, seventy of its own returns, and passes away as the new existence, to which its decay has given being, attains its first strength and vigour.

As an instance of the life-history of an eclipse, we may take the one which fell on New Year's Day, 1889. This eclipse goes back to May 27th, 933, when it was the second of a pair of eclipses. The other member of the pair only lasted for two *Saroses* later, and on June 28th, 987, our eclipse appeared for the first time alone. All this time it was a small partial eclipse, but the phase increased in magnitude at every return; and at its eighth appearance, August 11th, 1059, it was an annular eclipse. It continued as an annular eclipse until June 8th, 1564, the thirty-sixth appearance, but at the three previous occurrences it had been partly total and partly annular; the thirty-fourth eclipse, that of May 18th, 1528, being the occasion when the moon was closest to the node at conjunction. The thirty-seventh eclipse fell on June 20th, 1582, and was the last eclipse before the Gregorian reform of the calendar; the calendar date of the thirty-eighth, therefore, is July 10th, 1600, that being the New Style date corresponding to June 30th, 1600, Old Style. The eclipse has been a total one ever since; its fifty-third occurrence being the Algerian eclipse of December 22nd, 1870, and its fifty-fourth the Californian eclipse of January 1st, 1889. It will still continue to be a total eclipse for one hundred and forty years, and will be last seen as such at the sixty-second appearance, March 30th, 2033. It is a very large partial eclipse at the next return, April 11th, 2051, and at the following return, April 21st, 2069, the dying Phœnix gives birth to its successor, for it is followed on May 20th, 2069, by the first occurrence of a new series of eclipses. The two series run on side by side for eight returns, until the old eclipse reaches its end, as a very small partial eclipse, on July 7th, 2195—its seventy-first occurrence.

If we trace the shadow-tracks of the eclipse from its first occurrence as an annular eclipse in 1059, we find that it began in the southern hemisphere close to the pole; indeed the shadow-track intersected the earth's axis beyond the pole, so that there was no place where central eclipse took place at noon. The centre of the eclipse on the next occasion lay in south latitude 76°; that is to say, the place where central eclipse took place at noon, or the place where the shadow-track cut the earth's axis as seen from the moon, was in that latitude. The centre then moved swiftly north. In 1095 it was in south latitude 64°; in 1113 in south latitude 60°. Then for one hundred and sixty-two years it practically remained stationary, the reason being that the 1113 eclipse occurred near the autumnal equinox, and the *Saros* bringing the following eclipses a little further on in the year every time, the south pole was turned more and more towards the sun almost exactly at the same pace as the central shadow moved north. Directly the winter solstice was passed, however—the winter solstice of the northern hemisphere, that is—and the south pole began to turn away from the sun, the northward movement of the central shadow began to be felt; indeed the change in the presentation of the earth's axis exaggerated its effect, and every successive return of the eclipse showed a rapid rise in latitude, until the date of the eclipse had travelled on past the summer solstice. This fell in 1564, by which time north latitude 31° had been reached, the equator having been crossed before the

* The paragraph referred to at the beginning of the paper was therefore wholly wrong. No eclipse lasts 2755 years. The usual duration is 1262 years.

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eclipse of 1492. The northward pace was now notably slackened. In 1654 north latitude 48° was reached, and the eclipse was total in England—the last one total in this country except the celebrated pair of eclipses of 1715 and 1724. Three returns later, in 1708, north latitude 53° was reached; but shortly after this, the turning of the north pole from the sun caused the shadow to appear to turn southwards, and when it had reached the winter solstice the latitude had fallen to north latitude 36°. This was the celebrated eclipse of December 22nd, 1870, to observe which M. Janssen escaped from besieged Paris in a balloon. But now that the eclipse has passed the solstice, and the north pole is beginning once again to turn towards the sun, the latitude of the central shadow will move northwards with great rapidity, and by 2015 will have reached north latitude 85°. At the next return the shadow-track, though not yet quite clear of the earth, will pass above the north pole, and the eclipse will be total for the last time.

The effect of the triple *Saros* in reproducing, not only the general conditions of an eclipse, but also the very hour and locality, is very strikingly seen in the two eclipses of 1708 and 1762. Here the shadow track is nearly the same in both cases, and the central point has only shifted a few miles, lying in both instances near the boundary line between Europe and Asia, between the towns of Samara and Orenburg. Curiously enough—but this must be looked upon as a mere chance coincidence—the same eclipse will have its centre a third time in the same place, viz., in 1961; but the general direction of the shadow-track will then be very different.

The shadow-track at the third return after 1762, viz., in 1816, again runs in a similar direction though the central point has shifted, and for the third time Norway is the seat of a total eclipse. The next triple *Saros* brings us to the 1870 eclipse, when the track had shifted southward for a time.

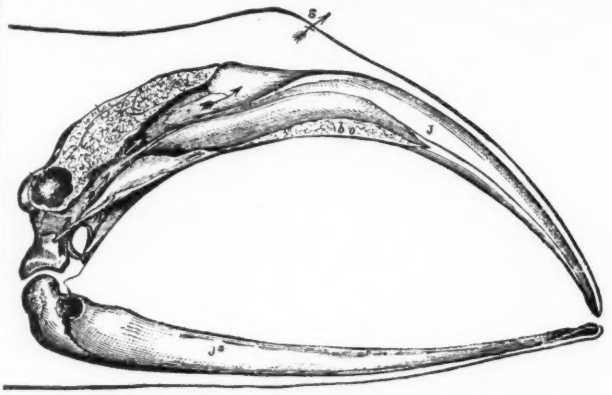
Such are a few of the relations produced by the incommensurability of lunar and terrestrial movements, combined with a curiously close approach to a precise commensurability. These are only a few of them, for I have entirely ignored the eclipses of the moon, or the solar eclipses at the opposite node, which of course have both a very definite relation to the series I have been considering. Still less have I included the numerous luni-solar cycles which, though useful for other purposes, have no relation to eclipses. The paper has, however, already proved very long, and may have been sufficient to have called attention to a subject in which less interest is taken at present than used formerly to be the case.

WHALEBONE AND WHALEBONE WHALES.

By R. Lydekker, B.A.Cantab.

SEEING that the substance so-called has nothing in common with true bone, many zoological writers object to the use of the term "whalebone"; and they have accordingly proposed the substitution of the word "baleen," which has been specially coined for the purpose. To our thinking, there is, however, no necessity for this substitution of a word of foreign origin for such a well-known English name, any more than there is for replacing the native term "black lead" by its foreign equivalent "graphite." Everybody knows what is meant by whalebone or black lead, while comparatively few are familiar with the terms "baleen" and "graphite"; and as the two former are every bit as good as their foreign substitutes, we prefer to employ them. If, indeed, there should exist any persons so misguided as to imagine either that whalebone is equivalent to the bone of whales, or that black lead has any sort of affinity with lead, we fear that the substitution of the terms "baleen" and "graphite" would not much aid in removing their ignorance.

The substance which we accordingly take leave to call whalebone is one of the chief essential characteristics by which the whalebone whales are distinguished from the toothed whales forming the subject of our article in the preceding number of Knowledge. As all our readers are probably aware, this substance is attached to the upper surface of the mouth of the whale, from which it depends in the form of a series of parallel, narrow, elongated,



Section through the skull of the Greenland Whale, with the outline of the soft parts. s indicates the position of the nasal aperture.

triangular plates, placed transversely to the long axis of the mouth, with their external edges firm and straight, but the inner ones frayed out into a kind of fringe. The longest plates of whalebone are situated near the middle of the jaw, from which point the length of the plates gradually diminishes towards the two extremities, where they become very short. There is, however, whalebone and whalebone, and whereas in the Greenland whale the length of the longest plates varies from some ten to twelve feet, while the total number of plates in the series is about 380, in the great rorquals or fin-whales, the length is only a few inches, while the number of plates is considerably less. To accommodate the enormous whalebone plates of the Greenland whale, the bones of the upper jaw are greatly arched upwards, while the slender lower jaw is bowed outwards, thus leaving a large space both in the vertical and horizontal directions, the transverse diameter of the space being much wider below than above. When the mouth is closed, the plates of whalebone are folded obliquely backwards, with the front ones lying beneath those behind them; but directly the jaws are opened, the elastic nature of this wonderful substance causes it to spring at once into a vertical position, and thus form a sieve-like wall on both sides of the mouth, the thin ends of the plates being prevented from pushing outwards by the stiff lower lip which overlaps them. By elevating its enormous fleshy tongue within the cavity thus formed, the whale causes the enclosed water to rush out between the plates, leaving such small creatures as it contained lying high and dry on the surface of the tongue ready for swallowing.

In structure, whalebone (which, by the way, although black in the Greenland whale, is white in some of the other species) is of a horny nature, and grows from transverse ridges on the mucous membrane of the roof of the mouth; being, in fact, nothing more than an ultra-development of the ridges on the palate of a cow, hardened and lengthened by an excessive growth of a horny super-

ficial or epithelial layer. The whole of this stupendous horny growth takes place, however, after birth, young whales having smooth palates, with no trace of the horny plates. Although at birth young whalebone whales show no traces of the substance from which the group derives its name, they equally exhibit no evidence of the presence of teeth. If, however, their jaws be examined at a still earlier stage of development, it will be found that there are a number of small teeth lying within a groove beneath the gum on each side of both the upper and the lower jaws. Previous to birth these teeth become absorbed, and thus never cut the gum. Their presence in this transitory stage is, however, of the deepest interest to the evolutionist, since they unmistakably indicate the derivation of the whalebone whales from ancestors provided with a full series of functional teeth. This, however, is not the whole of the story these rudimentary structures have to tell. From the recent investigations of Dr. Kükenthal, it appears that in addition to the above-mentioned tooth-germs, the jaws of very young whales likewise exhibit traces of a still earlier deciduous series of milk-teeth; thus showing that the former correspond to the permanent series of other mammals. Accordingly, these tooth-germs do not represent the functional teeth of the toothed whales, which, as we have seen in the article on that group, correspond to the milk-teeth of ordinary mammals. Even more remarkable are certain observations relating to the structure of these tooth-germs. It has been shown, indeed, that the teeth in the latter part of the series, when first formed, consist of a number of adjacent cusps, and that as development proceeds these cusps become completely separated from each other so as to constitute distinct individual teeth of a simple conical form.

This discovery is of the very highest import, since it serves to indicate how the numerous simple conical teeth of the dolphins and other toothed whales have probably been derived by the splitting and subdivision of originally complex cusped teeth more or less closely resembling those of the extinct zeuglodonts referred to in our article in the last number.

Being primarily distinguished from the toothed whales by their total absence of teeth after birth and the presence of whalebone in the adult condition, the whalebone whales present certain other distinctive characters to which we may now briefly allude.

In the first place, the whales of this group differ externally from all those furnished with teeth in that their nostrils open externally by two distinct longitudinal slit-like apertures; while, if we cut into the head, we shall find that there is a distinct organ of smell, of which all traces have disappeared among the toothed whales. Moreover, instead of the skull being invariably unsymmetrical in the region of the nose, as it is in the latter group, it retains the normal symmetry; while, instead of the mere nodules which in the toothed whales represent the nasals of other mammals, in the whalebone whales these bones are fairly well developed. Moreover, the lower jaw of any member of the present group may always be distinguished from that of a toothed whale not only by the absence of teeth, but likewise by the circumstance that each of its branches is much bowed outwards in the middle, while their anterior extremities are connected together only by ligamentous tissue, instead of by a bony symphysis of greater or lesser length. Many other points of difference between the two groups might be cited, but we have especially referred to those mentioned above, for the reason that while the presence of whalebone indicates that in one respect the members of this group are more specialized than their toothed cousins, in regard to the structure of the skull in the region of the nose and the retention of an organ of smell, as well as in the double apertures of the nostrils, they depart less widely from the ordinary mammalian type. And it is from this evidence that zoologists regard the two main groups of whales as being widely divergent branches from a common ancestral stock, if, indeed, they do not go so far as to consider that each has had a totally independent origin.

With regard to the number of forms by which they are represented, the whalebone whales are far less numerous than the toothed group, while the whole of them are included within a single family. What the group lacks in number is, however, amply made up by the great bodily size of its various representatives. Among the toothed whales, the sperm-whale alone attains gigantic dimensions; whereas in the present group there are several species, such as the Greenland whale, which nearly equal that enormous creature in bulk, while two of the rorquals far surpass it. This, however, is by no means all, for whereas the great majority of the dolphins and porpoises are relatively small cetaceans of less than twenty feet in length, the smallest member of the present group is the New Zealand pigmy whale, which attains a length of twenty feet, while next to this comes the lesser rorqual, whose length is frequently close on thirty feet.

Of the various genera of this group, the most specialized are the typical or right whales (*Balæna*), in which the black whalebone is far larger and more elastic than in any of the others, except the pigmy whale; while, in order to accommodate it in the mouth, the skull has the palate narrower and much more highly arched, and the two branches of the lower jaw more outwardly bowed than in the other members of the group. Externally, these whales—which are commercially of far greater value than the undermentioned rorquals—are characterized by the inordinately large dimensions of the head, by the smooth throat, the moderate length of the flippers, and the total want of a back-fin. So gigantic, indeed, is the size of the mouth in these whales that its capacity actually exceeds that of the whole of the other cavities of the body; and yet the size of the throat is so small as almost to justify the common nautical saying that a herring will choke a whale. There are but two well-defined species of right whales, viz., the Greenland or Arctic whale (*B. mysticetus*), and the southern right whale (*B. australis*), the latter of which was nearly exterminated some centuries ago in the Atlantic by the Basque whalers, while the former is only too likely to share the same fate at the hands of their modern successors in the Arctic seas. Of the two, the Greenland whale is decidedly the more specialized, having a much larger head and longer whalebone, and is in this respect *facile princeps* among its tribe; although, as it only measures from forty-five to fifty feet in length, it is inferior in point of size to the rorquals. The skeletons of both these whales are characterized by the whole of the vertebræ of the neck being welded together into a solid mass; and the same feature is exhibited by that of the pigmy whale (*Neobalæna*) of the Australasian seas, which, as already mentioned, is a mere dwarf among giants, as it does not exceed some twenty feet in total length. Agreeing also with the right whales in its smooth throat, the pigmy whale differs by having a small hook-like fin on the back, while its long and elastic whalebone is white instead of black. Far larger than the last, the great grey whale of the Pacific (*Rhachianectes*) forms a kind of connecting link between the right whales and the rorquals, having the smooth throat and finless back of the former, while its whalebone is even shorter

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and coarser than in the latter; the palate consequently is but little vaulted, and the entire head smaller in proportion to the body.

The remaining whales of this group are divided into hump-backs (*Megaptera*) and rorquals or finners (*Balænoptera*); both of which are characterized by the presence of a number of parallel groovings or flutings in the skin of the throat, by the presence of a back-fin (whence their name of finners or fin-whales), and also by the shortness and coarseness of their whalebone, which is generally of a yellowish colour. Their flukes are, moreover, less expanded than are those of the right whales; while, as already said, their heads are relatively smaller and lower, with the cavity of the mouth much less vaulted. In their skeletons, the vertebræ of the neck differ from those of the right whales in being longer and completely disconnected from one another; and in this respect the Pacific grey whale holds a position intermediate between the two groups. Hump-backs, of which there is but a single species, are specially characterized by the shortness and depth of the body, which behind the shoulder rises above the level of the back-fin, and by the exceeding elongation and slenderness of the flippers, which are about equal to one-fourth the total length of the animal. The female hump-back, which somewhat exceeds her partner in size, attains a length of from forty-five to fifty feet, or about the same as that of the Greenland whale. An enormous whale, believed to belong to this species, became some years ago entangled in the telegraph cable line off the coast of Baluchistan with three turns of the cable round its body. On the other hand, in the rorquals, the body is long and slender, while the flippers are small and pointed. Of the four well-established species of this genus, the blue or Sibbald's whale (*B. sibbaldii*)—the "sulphur-bottom" of the American whalers—enjoys the proud distinction of being the largest of all known animals, whether living or extinct, attaining the enormous length of from eighty to eighty-five feet; while the common rorqual (*B. musculus*) comes in a good second with a length of from sixty-five to seventy feet. Both the others are, however, considerably smaller.

As regards their distribution in time, right whalebone whales have left their remains commonly enough in the pliocene strata of all parts of the world, and they probably also occur in those of the miocene period; but, although a single vertebra from the eocene beds of Hampshire has been assigned to a member of this group, there is at present no decisive evidence that they had come into existence at such an early date. Since most of the pliocene species are of smaller dimensions than their living representatives, it appears that these marvellous creatures had only attained their maximum size shortly before the time when their very existence was to be threatened by the relentless hand of man.

Formerly the only members of this group of whales which were thought worthy of general pursuit were the right whales; the shortness of their whalebone, coupled with their relatively small yield of oil, and their tremendous speed, rendering the rorquals scarcely worth the trouble and risk of hunting. Of the two right whales, the Greenland species, as being the more abundant, received the greatest share of attention; and so relentless has been its pursuit, that it is now either well-nigh exterminated from many of its ancient haunts, or has retreated still farther north to regions almost impossible of access. As showing how the constant persecution in the Greenland seas has told upon the size of the comparatively few remaining individuals of this species, it may be mentioned that the eleven specimens killed there during the season 1890-91 yielded an average of less than 8 cwt. of whalebone, whereas in five taken during the same season in Davis Strait the average yield was more than double this amount. In consequence of this diminution in the number and size of the Greenland whale, the price of whalebone has of late years gone up enormously; and whereas some time ago whalebone of over six feet in length sold at £1000 per ton, in 1892 it had reached the enormous price of upwards of £2800 per ton. The southern right whale yields a smaller quantity of less valuable whalebone, now selling at from £1600 to £1800 per ton; the quantity obtained from a well-grown example varying from 800 to 1200 pounds. The amount of oil produced by a whale of the same species averages from eight to fourteen tons, of which the present market value is about £28 per ton. If the unfortunate animals are not allowed some respite, it is only too probable that the supply will before long cease altogether.

As another result of this growing scarcity of the Greenland whale, attention has been directed to the previously despised rorquals and hump-backs; the employment of steam whaling vessels, and the use of explosive harpoons, having enabled the whalers easily to cope with the greater speed of these cetaceans. At Hammerfest, a special "fishery" has, indeed, been established for the capture of rorquals, where the capture of these animals is now large. The products of these whales are, however, nothing like the value of those of the Greenland species; and if the latter, together with the southern right whale, be so nearly exterminated as to render pursuit no longer profitable, the supply of long whalebone will absolutely come to an end.

Cannot, we ask, something be done to check this short-sighted greed, before the opportunity is for ever lost?

GALLS AND THEIR OCCUPANTS.—IV.

By E. A. Butler.

FOR our next illustrations of gall formation we must look to a type of insect very different from those we have already examined. The aphides, or plant-lice, from the very nature of their food, the juices of plants, which they obtain by puncturing the twigs or leaves, necessarily more or less modify plant growth and produce shrivellings and distortions of various kinds. Such a result may be expected to follow the attacks of all species, but some go farther than this and produce actual galls, which externally closely resemble those caused by other kinds of insects. The natural history of this group is so peculiar that it will be necessary to sketch the plan of their development before the connection of the galls with the insects can be properly understood. There are many different kinds of aphides, and everyone is probably familiar with their general appearance. The soft green bodies, commonly called "green fly," which cluster in sticky crowds round the softest and tenderest shoots of rose trees, and the black ones which crowd equally thickly round the tops of broad-bean plants, are, perhaps, two of the most familiar examples. They form a well-marked division of the order Homoptera, which are distinguished from other insects by having four wings of a more or less similar appearance, and a pointed beak containing four fine piercing needles, and by passing through an incomplete metamorphosis—that is, never becoming a limbless, resting chrysalis, but having legs and remaining more or less active all through their life.

Assuming, then, that we know what sort of insects we are speaking about, let us take, to illustrate the group, the

species called *Schizoneura ulmi*, which makes galls on the leaves of elm trees. The eggs of this creature are exceedingly minute yellowish or brownish bodies, which are to be found, if diligently sought for at the approach of winter, in the crevices of the barks of trees which have borne the insect during the preceding summer. Each of these eggs represents the entire family of a single pair of insects. The mother was but little larger than the egg she produced, and she died immediately upon its laying. Sometimes, indeed, she dies before her solitary egg is laid, in which case the egg would be found in such situations as above described, but enclosed within the dried skin of its parent. Of course one would naturally expect that when these eggs hatch they would give rise to insects similar to those which produced them, or at least to creatures which by a process of development and growth would gradually become like them. But when we are dealing with aphides, such ideas must be put aside altogether, for here we find developed to a wonderful extent the phenomenon called "alternation of generations," a phrase by which is meant that forms, more or less different from one another, regularly succeed one another in a cycle by some process of multiplication, so that a number of "generations," so to speak, intervene before we arrive again at the same sort of thing that we started with. In the present instance, no less than seven such generations constitute the cycle, and these must successively appear, each being the viviparous parent of the next in the scale, before we arrive again at the egg with which we commenced. Some of these seven are pretty much alike, but the rest differ greatly.

It is obvious that if we are to speak intelligently of these different stages in the life-history of a single insect, we shall require distinctive names for the entire seven. No one of them, to the exclusion of the others, can be described as the insect itself; nothing short of the whole series can fairly be considered as representing this. Nor are they stages like the larva and pupa of other insects, the differences between which are no more than what are caused by a mere change of skin, so that the insect remains one indivisible creature throughout its life. On the contrary, in each one of these stages the insect may be represented by an indefinite number of separate and independent beings, which in fairness ought all to be taken into account in estimating the produce of a single egg, up to the time when the next egg appears. Of course these stages might be distinguished numerically, but names descriptive of their functions are preferable. Such a system of names was devised by Lichtenstein. They were expressed in French, and no thoroughly satisfactory English equivalents seem to be available. Not to worry our readers, however, with these rather complicated foreign expressions, we will render into English the most characteristic portion of the names, and thus we speak of the creature which issues from the above-mentioned egg as the "stem-mother" or "foundress." Buckton, the historian of the British aphides, gives this stage the name of "queen aphis," in consequence of certain resemblances between her functions and those of queen bees or wasps. If this name be used, however, it must be borne in mind that while queen bees and wasps are fully developed females which mate with male partners and produce eggs in the usual way, nothing of this sort takes place in connection with the queen aphis. On the whole, it will probably be productive of less confusion to use the term "stem-mother," implying by this that the form so designated is the first active six-legged member of the series, and that she is, as it were, the mother of the stock, the progenitor from whom the whole pedigree is derived.

The egg hatches in springtime, and the stem-mother, who has no wings and is therefore not likely to wander far, at once begins to attack the young leaves on the tree on which she was hatched, piercing them with the fine needles in her beak as soon as they unfold from the bud. The damage done to the tissues by the punctures induces an abnormal growth, and little cavities appear on the leaf, within one of which the stem-mother nestles. The leaves that have been attacked in this way now curl downwards and change colour, becoming pale and sickly-looking. Meanwhile the stem-mother continues to suck out their juices, grows, changes her skin two or three times, and after a few days begins to produce a family, with which she stocks the cavities of the curled leaves. They are little green things and are produced alive, so that no time is wasted in getting them set to work at the task of tapping the leaves of their juices. Some of these members of the second generation remain on the leaf which was their birthplace, but others crawl off to neighbouring leaves; ultimately they produce viviparously another set of offspring, at first similar to themselves, but destined to advance to a higher grade of development. By successive moultings they first acquire the rudiments of wings, and at length become fully equipped with four delicate transparent wings. These winged forms are all of the same sort, and all have the power, like their predecessors, of producing living young. They are known as "emigrants," because they soon make use of the power of flight which they possess, and float away to other trees, thus spreading their ravages over a wider area. By this time, then, we have a large number of creatures as the descendants of a single egg, spread far and wide, and yet no other egg has thus far appeared, nor indeed will do so till the end of the summer.

These winged emigrants do not live long, but each gives birth to about a dozen living young, at intervals of about half-an-hour, and then dies. We are now in the fourth generation, and these new creatures are very different from those that have preceded them, being wingless and very active. When first dropped they look much like eggs, and have to shed a thin skin before they can move their limbs; the casting of this membrane enables a number of minute hairs to shoot rapidly out from the surface of the body, and thus we have a kind of transformation scene going on, a little shining yellow stationary object changing in about half a minute to a hairy six-legged creature, which runs about quickly and soon covers itself with a kind of cottony down. Another generation of wingless creatures is again produced from these, and then we come in the sixth generation to something like the emigrants again, *i.e.* the members of this grade gradually acquire wings; but their function is quite different from that of the emigrants aforesaid, for they are to become the parents of the true males and females which, in the next generation, will appear for the first time. These winged creatures are smaller than the previous set, and are called by the rather inappropriate name of "pupa-bearers." They get their wings in July, and quickly make good use of them to wander in search of suitable places for the deposition of their brood. They settle on the bark of the selected elm trees, and there give birth to two sorts of beings, both exceedingly minute, and yellowish or orange in colour. These, which constitute the seventh generation, are the true sexes. Their sole function is that of reproduction, and hence all their energies are bent to this purpose. They take no food, and in fact the female has neither beak nor mouth, and her partner is almost in a similar predicament, for though he is born with a beak, he soon loses it and becomes as mouthless as his mate.

After having paired, the female establishes herself in a

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crevice of the bark, and there lays her single egg, which is large enough to occupy the whole of the cavity of her body. Having done this, she, or rather all that is left of her, at once dies, though she may, as we have said above, die even without depositing her burden, leaving it enshrouded in her withered skin. Thus, after having passed through a pedigree of seven successive generations of beings, we find ourselves back again at the stage with which the cycle commenced. The eggs lie on the trees throughout the winter, and next season the same series is gone through again. From a history such as this, it follows of course that by far the greater number of aphides seen during any particular summer do not originate from eggs at all, and that indeed, when compared with the number of living beings produced altogether, the total number of eggs is ridiculously small.

Now it is evident from the above that galls which are produced by insects of this sort differ in many respects from those which have previously occupied our attention. In the first place they are not associated with their fabricators throughout the whole cycle of their varied existence, but only during certain stages. Again, it is not the true female of the species, but the stem-mother, that originates these aphis-galls, and they are used by her and her immediate progeny till the migrating stage is reached. Moreover, the original puncture which started the gall is not made, as has always been the case hitherto, for the lodgment of an egg, but simply for the obtaining of food. In fact, no egg is ever associated with the gall at all. The galls produced by the different species are of various shapes and sizes, and as they shelter communities, not individuals, their size bears no relation to that of the individual aphides; some are as large as hazel nuts, and some occasionlly reach the size of a ripe fig. They are found frequently on the stalks of leaves, as in Fig. 12, which shows one commonly found on the stalks of poplar leaves; sometimes they rise from the blade of the leaf itself. They are hollow, and have an opening at the end, out of which the winged "emigrants" escape. If opened they are found to contain not only a company of aphides, but a globule of sweetish liquid as well, and a quantity of a white mealy powder, with which also the bodies of the insects are dusted. The nature of the liquid and its exact relation to the inhabitants of the gall is doubtful; it is often too large in amount for there to be a possibility of its being entirely a secretion by the insects, and some naturalists suppose it to be in part at least exuded sap, which has escaped through the many punctures inflicted by the aphides upon the walls of the gall. The mealy powder clings to the surface of the globule, and thus prevents it from injuring the delicate insects amongst which it lies. According to Dr. M. C. Cooke, liquid of this sort found in large elm-galls is collected in France and used, under the name of "elm-water," as a lotion for sore eyes.

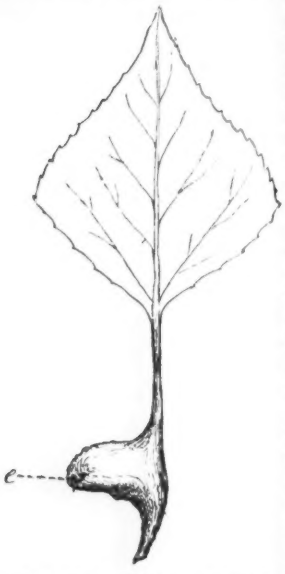

Fig. 12.—Aphis Gall on stalk of poplar leaf. *e*, Hole for exit of aphides.

Nothing more beautiful can be imagined in the way of galls than those made on the spruce, fir, and larch by aphides belonging to the genus *Chermes* (Fig. 13). They closely mimic fir-cones, so closely in fact that a section needs to be made before one can be convinced that they are not a legitimate fruit of the trees. They are, of course, smaller than the actual cones, and this would help to distinguish them, were it not that they are so strongly suggestive of young cones. The life-history of the creatures is less intricate than that detailed above, and only a few points need be noticed. The mother of the tribe starts the gall, but she does not produce living young. She lays a number of eggs, which are attached to the tree immediately around her body, each by a thread-like stalk. The larvæ hatched from these by their punctures increase the growth of the gall, and cause the adjacent leaves to swell so much as to meet one another at certain spots and enclose the insects within cavities. In this way a many-celled structure is built up, which externally resembles a miniature fir-cone. As time advances, the cone dries up, and its component scales then open out so as to leave free exit for the contained insects.

Fig. 13.—Gall of *Chermes abietis*, mimicking fir-cones. Magnified two diameters.

Only one other instance of gall-growth need now be referred to, and with it we revert to the type which formed our earlier illustrations, viz., gall-formation on the insertion of an egg. But though the type of gall is similar to those formerly described, the insect cause is totally different, belonging to an order we have not yet had occasion to mention, viz., the Coleoptera, or beetles. It is an agricultural pest, known as the cabbage gall weevil. This insect is a stumpy, hard-skinned, black-bodied beetle, with a long, slender, curved beak, halfway down which are inserted the elbowed antennæ. The mouth is at the tip of the beak, and here are situated a minute pair of jaws, with which the little pest can pierce the skin of a cabbage-stalk. The beetle is by no means a large one, being only about one-eighth of an inch long from tip of beak to end of body. When it is alarmed it tucks its beak under its body, which is slightly grooved for its reception, and folds its legs up closely, so that its size seems much reduced, and it resembles a little lump of dirt.

The female insect with her beak pierces that part of the cabbage stem which is below ground, and lays an egg in the hole. Many such holes may be formed by the same beetle near together on the same stem. A gall soon forms round each puncture, and sometimes quite a cluster of rounded knobs may be seen on the stem. The egg hatching produces a footless maggot, which lives on the material of the gall. When it is full grown it gnaws its way through the rind of the gall and works itself into the earth, where it fashions a little cell in which it turns to a chrysalis; this becomes a perfect beetle the next season. In all its stages it is a very hardy insect, being able to endure a good deal of interference with its comfort without evil consequences. It will even survive being frozen stiff when in the pupal condition. Though these galls are small, they may become harmful by exhausting the plant, when present in great numbers. Not only the cabbage crop, but turnips also are subject to their attacks, though they seem less injurious in this case. This little beetle, which, if allowed to multiply too greatly might become a serious pest, has had bestowed upon it a name by no means commensurate with its diminutive size, for in our cabinets it stands ticketed *Ceuthorhynchus sulcicollis*.

WHAT IS THE SUN'S PHOTOSPHERE?

By A. C. Ranyard.

PERHAPS it may be well to explain, for the sake of readers who are not familiar with the long names which have been given to various regions of the sun, that the photosphere is the shining sphere we generally speak of as the sun. It is in fact only a part of the sun, but it is the part with which we are most familiar, because it can be seen with the naked eye, and can be examined with the telescope under ordinary conditions.

Immediately outside the photosphere is a region in which coloured prominences can be detected with the spectroscope under ordinary conditions. This region immediately above the photosphere is called the chromosphere; it has no definite outer limit, though it has a comparatively sharply defined lower limit, marked out by the upper surface of the photosphere. During a total solar eclipse the chromosphere, or the upper portions of the chromosphere which are not hidden by the moon, can be seen with the naked eye and with an ordinary telescope, extending to a greater height above the sun's limb than they can be traced with the spectroscope under ordinary daylight conditions; and towering to a vast height above the chromosphere are still fainter structures and rays, extending sometimes to a distance of more than a solar diameter from the moon's limb. The faint structures extending into the outer region are collectively spoken of as the corona, but there is no defined limit separating the corona from the chromosphere. Bright lines, indicating the presence of hot vapour, can be detected with the spectroscope extending to a great height in the corona, and the structures of the corona can be traced down through the region of the photosphere in a manner which would lead us to conclude that the coronal structures, as well as the prominence structures of the chromosphere, have their origin in a region below the bright surface of the sun.

To define the photosphere as the highly luminous spherical surface which surrounds the nucleus of the solar nebula is not to explain what it is. The beautiful photographs of parts of the solar photosphere which, by the kindness of Dr. Janssen, I am able to lay before readers of Knowledge, show that the shining surface is broken up into a series of masses arranged with a certain degree of parallelism in adjacent parts, like the cirrus clouds in a mackerel sky; and in Plate I., which represents the photosphere on a larger scale than Plate II., it will be seen that the elongated bright masses are striated across their length, and that in many cases they break up into a series of rounded cloud masses arranged in rows.

I have had two classes of plates printed—one in a chocolate-brown ink, which has been over-exposed in preparing the plate for printing so that it only shows the brightest parts of the photosphere, and another in a dark platinotype tinted ink with less exposure, so that the details of the brightest regions are sacrificed in order to show fainter and more nebulous parts. Those who take an interest in the matter will be repaid by comparing the two classes of plates. About half of the edition of Knowledge has been issued with the chocolate-brown plates, and the remainder with the dark platinotype tinted plates.

It was long ago pointed out by Dr. Janssen that a reticulated pattern is traceable in the arrangement of the cloud masses of the photosphere. In the regions corresponding to the strings of the netting the cloud masses are clearly defined. They are separated by numerous dark interspaces, and the elongated masses appear to stand up or to be arranged more or less radially to the sun's centre; whereas in the areas corresponding to the meshes of the net the structure appears to be hazy or blurred, and the elongated cloud masses lie more or less parallel to one another as if raked out in a plain at right angles to the solar radius. The phenomena presented by solar spots and the dark interspaces between the clouds of the photosphere would lead us to conclude that the photosphere is a comparatively thin layer of brilliantly shining clouds, which is torn and churned by innumerable currents, as indeed we might expect if all the uprushing streams of the chromosphere and corona pass through it.

In the very interesting lecture on "Flame," delivered before the recent meeting of the British Association at Nottingham, Prof. Smithells concluded his address by asking his audience to consider what must have been the condition of the earth in past ages.

"The earth," he said, "is known to be a cooling body, and also an oxidized body. At one time it must have been too hot for the oceans to have existed upon it in a liquid state, and at a still more remote period all the waters of the earth probably existed as an enormous gaseous envelope of uncombined hydrogen and oxygen. Chemistry forces us to imagine an intervening time at which this oxygen and hydrogen would begin to combine. During that period, huge cosmical flames would rend the atmosphere. The steam formed would descend to the hotter strata of the pre-geologic atmosphere, would be dissociated and sent forth again to combine in the upper atmosphere, causing an incessant celestial pyrotechny," which the lecturer concluded must have caused the earth—as seen from a distance—to resemble the sun as known to solar physicists at the present time.

I am not able to adopt Prof. Smithells' theory as to the constitution of the solar photosphere, but it seems to me that too little attention has been devoted to the explosive combinations which Prof. Smithells points out must take place in some region of a highly-heated atmosphere of mixed gases. Since the day when Sir John Herschel calculated the heat which would be given out during the burning of a globe of coal as large as the sun, and compared it with the heat which is given out by the sun in six thousand years, it has been too frequently assumed in popular astronomy books that no chemical combinations can be taking place upon the sun; but without chemical combination and explosions it is very difficult to conceive of an adequate cause for the swift uprushes of matter we observe in the chromosphere, and the still more gigantic uprushes whose existence is evidenced by the structures observed in the corona.

The great deviation from the radial of many of the streams of matter projected into the chromosphere, as well as the tangential rays of the corona, point to the conclusion that the region of these explosions cannot be situated at any very great distance below the photosphere. It is possible that such explosions may take place in the region of the photosphere, but it does not seem probable that the intense light of the photosphere can be due to burning or chemical combination, for we know of no flames comparable in brightness with the brilliant incandescence of the electric arc light, and the incandescent carbon candle of an electric light is not as bright as the solar photosphere. The most brilliant lights we know of are produced by the intense incandescence of solid substances. Thus a mass of lime in the dull oxy-hydrogen flame is brighter than any gas flame we can produce, but, according to the measures of Foucault and Fizeau in 1844, the solar surface was found to be one hundred and forty-six times more brilliant than the calcium light; and Prof. Langley

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in 1878 found the surface of the sun to be five thousand three hundred times brighter than the molten metal in a Bessemer "converter." There is evidently a great range in the light-giving capacity of incandescent bodies, but the brilliance of the solar surface does not greatly exceed the brightest incandescence of the most refractory bodies, obtainable by means of the electric current; and it should be remembered that in laboratory experiments the intensely heated part of a glowing rod of carbon, or other refractory substance, is being cooled by adjacent cold parts, and it is therefore probably not as hot as if the experiment were made on the solar scale.

Such considerations would lead us to conclude that the light of the photosphere must be due to the brilliant incandescence of the most refractory substances present in the sun, at a level when they are just on the point of being driven into vapour.

To those who would urge that we do not know what would be the brightness of an explosive flame two thousand miles thick, I would reply that such explosions could not go on continuously over a wide area—there must be room for the descent of the associated products of combustion, and an interval of time for the ascent and cooling to the temperature of explosive combination of the ascending elements; also, that in such a mixed mass of vapours as must exist in the well-churned region of the solar photosphere, the brightness of the explosive flame would probably be considerably less than the brightness of the flame where pure gases combine; and further, that a flame containing metallic vapours, such as we know are present in the region immediately above the photosphere, would give a spectrum showing many bright lines, which it seems probable would not all be similarly reduced by absorption, so as to give the appearance of a comparatively uniform continuous spectrum, crossed by dark lines, such as we see when the spectrum of the light of the photosphere is examined.

It has recently been suggested by more than one physicist that it is possible that gases only give out their characteristic bright-line spectra when some chemical or electrical change is going on in their molecules; but it seems to me that this suggestion (and it is nothing more than a speculative suggestion) is sufficiently negatived by facts already in our possession. Prof. Smithells has himself shown that iodine vapour may be rendered incandescent by merely heating it in a glass tube, warmed to a red glow in a Bunsen burner; and following the analogy offered by the radiation of solid bodies, we should expect that a gas which absorbs as freely as iodine vapour would also radiate freely, and that other vapours which absorb radiations less greedily than iodine vapour would only commence to radiate when raised to temperatures higher than can be conveniently obtained for laboratory experiments.

The phenomena of the sun itself also seem to indicate that the incandescence of vapours in the chromosphere is not due to chemical changes, but is more probably a mere heat effect. If the incandescence were due to chemical change, we should expect all the bright lines corresponding to any particular element to extend to the same height above the photosphere, namely, to the height at which the chemical change affecting the element was taking place; but the lines in the spectra of the same element extend to very different heights, and that not always in the order of their brightness.

Hitherto solar physicists have generally attempted to account for the spectral phenomena presented by the sun as mere heat effects caused by radiation from hot matter, and absorption by cooler gases; and it is no doubt profitable to pursue this method without making assumptions as to unknown electrical effects, and the chemistry of temperatures with which we are not familiar in terrestrial laboratories. But it must be remembered that more than half of the lines of the known solar spectrum remain unaccounted for, and that no lines corresponding to whole groups of chemical elements have as yet been recognized in the solar spectrum.

In the last number of Knowledge I endeavoured to show that the vapours present in the chromosphere and corona cannot form a solar atmosphere in which gases rest in equilibrium stratified into absorbing layers, as is so frequently assumed. The proof turns upon what we know of the intensity of solar gravity at the level of the photosphere, and upon the assumptions which it seems safe to make with regard to the temperature of the region immediately above the photosphere. If the photosphere consists of incandescent clouds of liquid or solid particles of matter similar to the matter of which the earth is composed, the general temperature of the region cannot be much above the temperature at which similar matter would be driven into vapour in terrestrial laboratories. It may be a little above such a temperature, because the matter of which the photospheric clouds are composed may be continually falling from a cooler outer region towards the hot solar nucleus.

Two classes of observations made during total solar eclipses tend to support the theory that the photosphere is composed of incandescent solid or liquid particles, for they show that it is highly probable that minute particles, many of which have diameters that are small compared with the wave-length of light, exist in the corona and extend down into its lower regions. When the corona is examined with a suitable polariscope, strong polarization colours, which extend down to close to the moon's limb, are observed, indicating a condition of radial polarization of the coronal light such as can be accounted for by dust polarization in the region of the corona. Secondly, the solar absorption lines have been observed in the coronal light down to the brilliant region near to the moon's limb, indicating that the corona chiefly shines with light which has been received from the sun and has been dispersed by liquid or solid matter in the coronal region. Most chemists and physicists will therefore, no doubt, agree that we are reasonably safe in assuming that the temperature of the coronal region cannot exceed 10,000° Cent.

The narrow character of the lines in the spectrum of the chromosphere seems to indicate that the gaseous pressure in the region where they exist must be very small compared with the pressure of the earth's atmosphere at the sea-level; but assuming that the gaseous pressure at the level of the photosphere is equal to the pressure of our atmosphere at the sea-level, and assuming the height of the solar atmosphere to be the height at which the pressure is reduced to a millionth of a millionth of the pressure at the level of the photosphere, we can calculate the height of a hydrogen atmosphere at any temperature with solar gravity equal to $27\frac{3}{4}$ times terrestrial gravity. Thus, at a temperature of 2457° Cent., the height of a hydrogen atmosphere about the photosphere would be only 270 miles, and at a temperature of 27,027° Cent. its height would be 2700 miles.

It will then, no doubt, be asked, can we, with such a rapid decrease of densities as is indicated by the above results, retain the old idea that the photosphere is a layer of clouds floating in the solar atmosphere? We know nothing of the temperatures within the photosphere, and without a knowledge of such temperatures we cannot determine the depth at which the density of the solar

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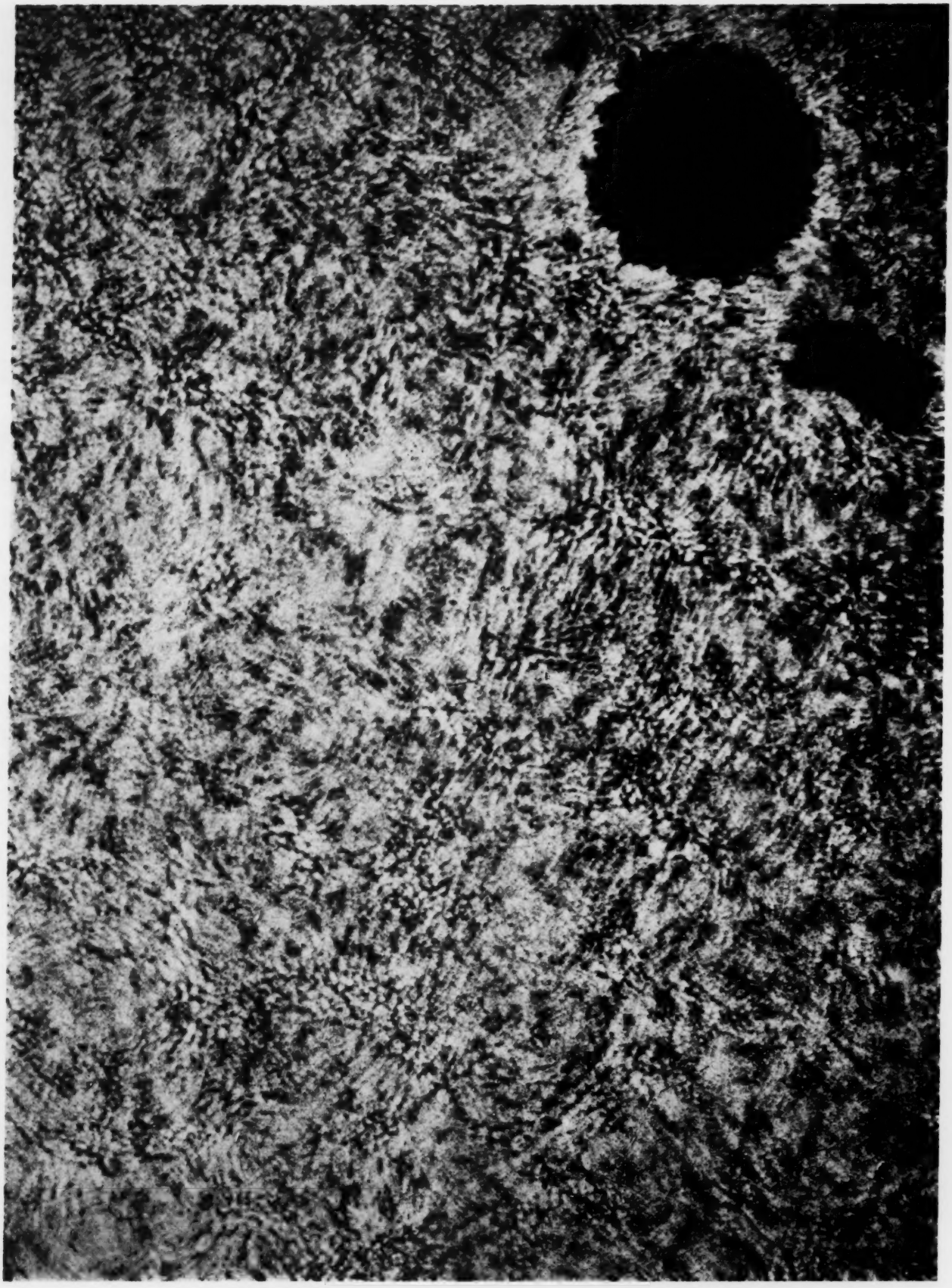

Plate I.—PHOTOGRAPH OF SUNSPOTS AND THE SOLAR PHOTOSPHERE.

Taken by Dr. JULES JANSSEN, at Meudon, on the 10th of June, 1887, with a refractor of 5-inches aperture. Diameter of the Sun's image, if on the same scale as in the Plate, one and a half metres.

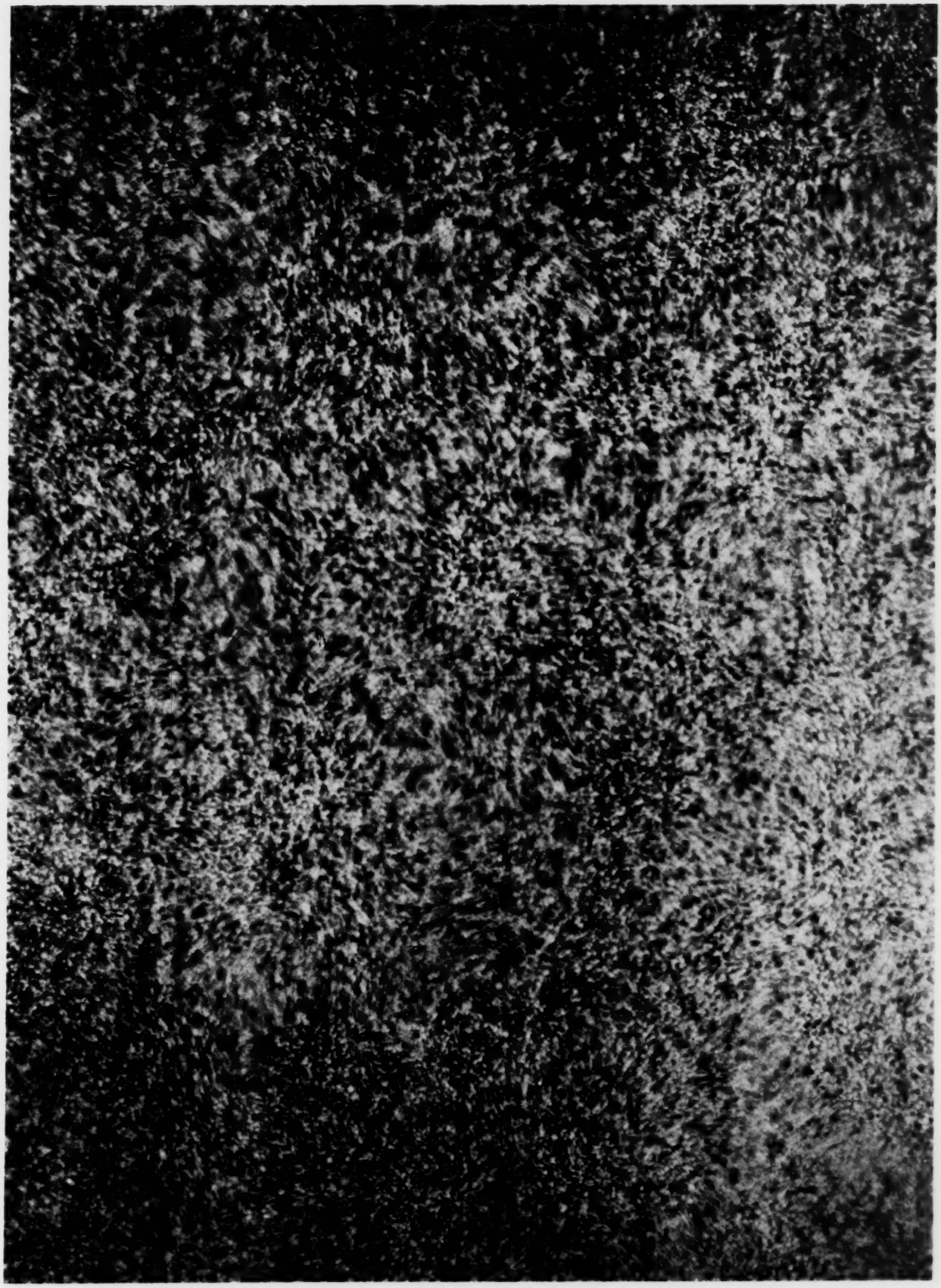

Plate II.—PHOTOGRAPH OF THE SUN'S SURFACE, SHOWING THE STRUCTURE OF THE PHOTOSPHERE.

On a scale of three-quarters of a metre to the Sun's diameter. From a Photograph by Dr. JANSSEN, taken at Meudon in 1892.

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atmosphere would double. No doubt the photosphere would act as a screen, preventing radiation from the solar nucleus, and the temperatures within the photosphere would probably be much higher than in the coronal region.

The volume of a gas varies as $\frac{\tau}{273}$ where τ is the absolute temperature in degrees Centigrade, and if the solar atmosphere extends as high as the level of the photosphere, the average temperature of the material within the photosphere will need to be enormously great, for the average density of the sun is only about a quarter as great as that of the earth, viz., 1·444 times the density of water.

Some vague idea as to such temperatures may be gathered from the consideration that with a gas obeying Boyle's law, and with gravity remaining uniform as at the level of the photosphere, an atmosphere of hydrogen (at a temperature of two million seven hundred and thirty thousand degrees Centigrade, measured from the zero of temperature −273° Cent.) would increase in density a million million million times in descending from the photosphere to a depth of 405,000 miles; for other gases, or a mixture of vapours, the rate of increase of density would be still more rapid. But the assumption that gases above their critical temperature when greatly compressed continue to obey Boyle's law is probably not permissible, for at low temperatures Boyle's law only approximates to the truth when the free paths of gaseous molecules are long compared with the molecular diameter.

It is not, however, necessary to assume that the incandescent clouds of the photosphere are floating in an atmosphere, as clouds of water vapour float in our atmosphere. In the case of terrestrial clouds, each little globule of water is no doubt continually falling, but it falls very slowly because of its small weight and the relatively large surface which is exposed to the resistance of the atmosphere. The weight of a small particle decreases as the cube of its diameter, while the surface which it exposes to a resisting atmosphere only decreases as the square of its diameter; consequently, the smaller the particle, the slower will be its rate of falling through a resisting atmosphere.

A minute particle in the photosphere would be retarded in its fall under the action of solar gravity by the backward kicks of molecules evaporated from its under surface exposed to the radiation from the heated centre. We should expect to find such falling particles checked in their downward course most rapidly just before they were finally evaporated, for two reasons; (1) because the weight of the falling particle would have already been greatly sweated away, and the total weight of the particle would bear a smaller proportion to the weight of the molecules evaporated towards the heated centre in a unit of time, and (2) because we should expect the force and number of the backward kicks to increase very rapidly when the particle enters a region where the heat is such that it will rapidly be completely evaporated.*

We should therefore expect small particles, falling towards a very hot body, to accumulate at a level where their falling motion was thus rapidly checked, and if the particles consist of matter which cannot be driven into vapour until it has attained a white heat, we should expect a layer of such particles to shine like a brilliantly incandescent cloud. It is therefore conceivable that the photosphere might lie far above the summit of the solar atmosphere. But the great inclination to the radial of many of the prominence structures thrown upwards into the region of the chromosphere and corona seems to point to the conclusion that the region from which the explosions take place cannot be situated at a great depth below the photosphere, and one can hardly conceive of explosions taking place which result in driving matter outwards unless there is some fulcrum to drive from, as there would be if explosions took place within a solar atmosphere in which the resistance to motion is greater in a downward than in an upward direction.

The great tenuity of the gaseous matter outside the photosphere is, it seems to me, evidenced by the narrow character and want of absolute blackness of the dark lines in the Fraunhofer spectrum, as well as by the narrowness of most of the bright lines, of the incandescent gases of the chromosphere. These come from a lower region, probably of greater pressure and temperature, and in the case of great outrushes the chromosphere lines are sometimes broadened and reversed in a complicated manner, implying pressure and overlapping streams of gas at different temperatures; but as a general rule the lines of the chromosphere spectrum are narrow, indicating long free paths and uniform vibration of the radiating gaseous molecules, such as only can be conceived of in a gas of extreme tenuity.

The dark lines of the Fraunhofer spectrum are, as a general rule, far from being absolutely black, proving that only a portion of the light of the wave-length radiated by the photosphere has been lost in its passage through the absorbing region; whereas the old experiment of Kirchhoff with the flames containing sodium and lithium vapour, proves that a few inches, or decimal parts of an inch, of vapour in which the molecules are comparatively close together, is sufficient to give an amount of absorption which materially darkens the absorption lines produced in the whole thickness of the solar envelope. With absorbing molecules very widely and sparsely scattered, only a small portion of the wave front corresponding to a ray of light would be interfered with in its passage through the absorbing region.

* The mean velocity of hydrogen molecules at a temperature of 2184° Cent. is 3·18 miles per second, and the mean velocity of hydrogen molecules evaporated from a surface heated to 2184° Cent. must be much greater than the mean velocity of molecules of hydrogen gas at a temperature of 2184° Cent., for the swiftest molecules are the first to separate themselves from the attracting molecules of a heated surface. Hence evaporation, by lowering the average velocity of the molecules left behind, cools an evaporating surface.

Science Notes.

The microscopic hairs on the leaf of the hop would appear to partake in a small degree of the properties of those of the closely-related stinging nettle. The peculiar form of eye trouble spoken of as hop-picker's ophthalmia, seems at any rate to be ascribable to these hairs, which adhere to the hands and subsequently get rubbed into the eyes.

The fastest mechanism, artificial or natural, made to penetrate water for any considerable distance, is according to Mr. Jeremiah Head, Thornycroft's torpedo boat, "Ariete," which on trial made 30·16 miles per hour.

M. Lionel Declé, in an account of the marriage customs of the Matabeles, mentions one feature which is, we believe, quite singular. The husband does not buy his wife, and although there is a suggestion of a memory of marriage by capture in the details of courting and in the avoidance of the parents-in-law, she would appear to remain her father's property. When children are born, the father has to buy them of his father-in-law, or, failing this, they revert to the mother's family.

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Aerial mechanisms are capable of very much greater speed. Canon Tristram told the biological section of the British Association in his address—which, through his unfortunate illness, was read by Sir William Flower—that Herr Gätke holds that godwits and plovers can do their 240 miles an hour, and the spine-tailed swift, according to Dr. Jerdon, can breakfast in Ceylon and sup in the Himalayas on the same day.

A very interesting topic, which is winning its way to attention, is the periodic and secular variation of the latitude of places on the earth's surface. Prof. Chandler has been laboriously investigating these movements for some time. He has examined records extending over the last half century, and including 33,000 observations of latitude, and has come to the conclusion that the observed value of latitude is the resultant arising from the superposition of two periodic fluctuations. These are—(A) one of 427 days due to a separation of the axis of rotation from the chief axis of inertia, and (B) an annual one due to the periodic shifting of the earth's centre of gravity in connection with seasonal redistributions of moisture.

Herr Alfred Möller has been conducting a series of observations at Blumenau, upon the economy of those leaf-cutting ants described in "The Naturalist in Nicaragua," and he finds that they not only cultivate fungi, but also that they have by judicious selection evolved a specially suitable variety, with peculiar swollen lateral branches. The fungus garden is an enclosure, protected of course from the light, and thither the strips of leaf are taken, and crushed up by the jaws of the ants, to supply their crop with organic food. So efficient is the weeding out of unsuitable material by these little horticulturists, that some of the earth of the garden, grown in a nutritive solution, gave a perfectly pure culture, free even from bacteria. The ants appear to subsist entirely on their specialized fungus knobs.

The Rev. J. Mathew has been studying various Australian rock and cave drawings. Many of these, it has long been known, are of a character far above the possibilities of existing aboriginal work, and indicative of an altogether higher level of civilization in the artists. One he describes is in red, blue, yellow, black, and white, and represents a figure dressed in a long robe and with the head surrounded by a kind of many-coloured halo. Mr. Mathew has found on one such halo certain marks which he interprets as the name of the chief god of Sumatra, and he also finds many other facts, the frequent presence of a sacred crocodile for example, which incline him to give these interesting markings a Sumatran origin. The natives can tell nothing about them, simply regarding them as bogies. He thinks, however, the crude religious notions of the aborigines may have been derived from the forgotten predecessors of the Anglo-Saxon colonist, to whom he ascribes these drawings.

Letters.

[The Editor does not hold himself responsible for the opinions or statements of correspondents.]

To the Editor of KNOWLEDGE.

THE SUN AS A BRIGHT-LINE STAR.

DEAR SIR,—I have been greatly interested in reading Miss Clerke's valuable and suggestive paper on "The Sun as a Bright-line Star," and the discussion to which it has given rise in the August and September numbers of KNOWLEDGE. May I be allowed, however, to point out that an important matter seems to have been overlooked by those who have taken part in the discussion. I refer to the *double reversal* of the H and K lines of the faculæ. A positive enlargement from a photograph taken at the Kenwood Observatory is sent herewith to the Editor. It clearly shows the bright H and K lines, with a central dark line, not only in a facula, but also on the disc as far as the slit extended. We here have evidence that a large area of the sun's surface was uniformly covered with a layer of calcium vapour hotter than the photosphere below it, and this again was capped by cooler calcium vapour which exercised sufficient absorptive power to cause a dark line to appear in the centre of the bright line originating in the hotter layer. Instances of double reversals of H and K extending without interruption for great distances are very common. Sometimes the lines can be traced entirely across the solar disc. The two bright components of the doubly-reversed lines are about equal in width to the central dark component. In certain cases portions of one of the bright components seem to be missing, while the other bright component is unbroken. Where the slit lies across a facula the two bright components widen and increase in brilliancy. Their form is then spindle-shaped, and the central dark line has become fainter and narrower. The accompanying photograph perfectly illustrates this point. Two causes may be involved in bringing this about. In the first place the increased thickness of the radiating calcium vapour (assuming a facula to be an elevation in the photospheric calcium stratum) tends to increase the brightness of the lines and also to widen them, on account of the increased radiation on both sides of the centres of maximum brilliancy. Again, if we assume the cooler calcium to overlie the hot calcium in a layer of uniform depth (a depth necessarily greater than the height of the faculæ), then the absorption should be least in the faculæ, where the overlying stratum of cool vapour is thinnest.* I am inclined to think that the actual appearance of the lines is such as to indicate the simultaneous existence of both these conditions.

Now let us consider the case of Mira Ceti. Suppose the thickness of the layer of cool calcium to be increased to such an extent that not only the centre but the whole of the bright line is blotted out. This might occur even if the H and K radiations of the faculæ were abnormally bright. In the sun it is extremely uncommon for the more refrangible hydrogen lines to be radiated by faculæ. Nevertheless, it is not difficult to imagine conditions favourable to this result. Under these circumstances, if there were insufficient cool hydrogen in the atmosphere of Mira to absorb the radiations of the lower regions, we should have a spectrum showing H and K broad and dark, and the series of hydrogen lines bright, with the exception of that near H, where the absorption of the calcium would have blotted it out.

Miss Clerke's explanation of the absence of the hydrogen H line in Mira, therefore, seems to me a plausible one. But the apparent similarity between this star and the sun appears to be increased rather than diminished by such a conclusion. Spectroscopists would do well to heed Miss Clerke's suggestion as to the collection of further data for the elucidation of this important subject.

Very truly yours,
GEORGE E. HALE.

* Should these ideas be confirmed by the results of future investigation, it might become possible to roughly estimate the height of a facula by the character of the double reversal of the H or K line in it.

[Prof. Hale's letter was received just as Knowledge was going to press, and I have consequently not been able to reproduce for readers of Knowledge the interesting photograph forwarded by him, but I hope to do so on a future occasion.—A. C. Ranyard.]

THE ABSENCE OF A LUNAR ATMOSPHERE.

To the Editor of Knowledge.

Dear Sir,—There seems to me so simple an answer to this question—what has become of the lunar atmosphere? that it is probable the suggestion has been made many times before. However, I have not seen the idea suggested, and therefore submit it to your readers. I would suggest that the atmosphere has not been drawn away from the moon, but that it is merely *frozen*.

It is well known that oxygen and nitrogen condense to a liquid at something under $-140°$. At a lower temperature they solidify. The moon is a cold body. Let it be granted that the temperature is below $-140°$, and what would become of the atmosphere? It would only exist in the liquid or solid state.

Possibly, in the absence of any pressure a much lower temperature than $-140°$ would be required; but that is immaterial. In the protracted lunar night—a fortnight long—the degree of cold might be so great, and the atmosphere therefore frozen so hard, that the heat of the lunar day would be utterly unable to volatilize it.

Yours faithfully,

C. W. Sweeting.

[Profs. Langley's and Very's observations seem to point to a temperature near to the freezing point of water during the lunar day in the neighbourhood of the moon's equator.—A. C. Ranyard.]

To the Editor of Knowledge.

Dear Sir,—A method of readily comparing two photographs for the purpose of detecting new stars (or missing stars) has occurred to me, which would obviate the necessity of tedious comparisons and measurements.

My method depends upon the fact that if a negative and its positive are correctly adjusted, face to face, then no image is transmitted, the field is neutral; but if the negative or positive is not identical, then the difference is apparent on inspection.

To apply this in practice, I propose to take an *old* star negative, not too dense, and compare it with a positive film, also wanting in density, which has been printed from a *recent* negative; when these two are exactly superposed, any new stars will at once become conspicuous to the eye as white spots, and any stars which have disappeared will be evident as black spots; or a print may be taken, thus showing all differences between the two photographs.

I think this method of examination would show very slight changes in nebulæ, &c., which might otherwise escape the eye.

If the two pictures are allowed to be slightly out of adjustment, then all objects are thrown up in relief, giving nebulæ, &c., a very substantial appearance.

I am sending a negative and positive, taken from one of the collotypes in Knowledge, to make the matter clear, and you will see that I have put a few extra stars on the back of the negative.

Yours faithfully,

F. H. Glew.

[The method proposed by Mr. Glew seems to me likely to be very useful.—A. C. Ranyard.]

LIGHTNING PHOTOGRAPHS AND SOME PHOTOGRAPHIC DEFECTS.

By A. C. Ranyard.

THE *Graphic* of 19th August contained a picture made from the photograph reproduced in Fig. 1, together with the following paragraph:—

"A Photograph of a Storm.—Dr. W. D. Hemphill, of Kingstown, to whom we are indebted for the photograph we reproduce, informs us that the negative was taken on Wednesday, August 9th, at 11 P.M. The lightning on the left of the picture is the ordinary stream coming from the clouds above; but that on the right is what appeared to be a ball of fire, which fell direct into the sea, and like potassium when thrown into water, darted about on the surface. The ball of fire carried with it a trail of light, leaving smaller balls here and there, and one of these passing a gas-lamp, illuminated the glass as shown in the photograph. The display was one of the most brilliant and vivid ever beheld, and fortunately the camera happened to be pointed in the direction, as the knotting and twisting of the threads of light resembled the course of a ball of wool played with by a kitten more than anything else."

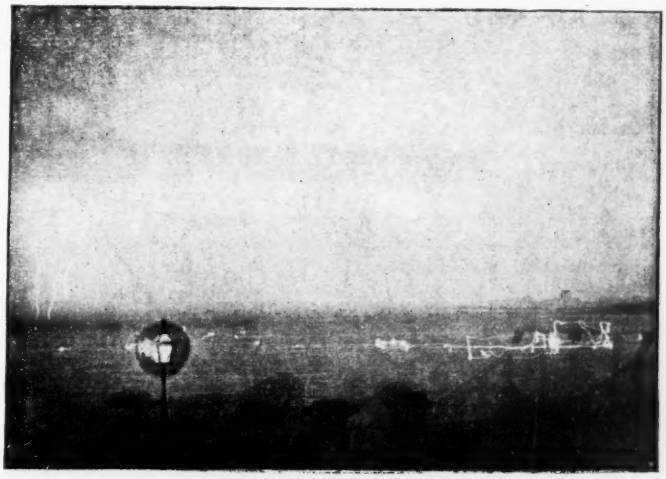

Fig. 1.—Supposed photograph of ball lightning, taken by Dr. W. D. Hemphill, August 9th, 1893, at 11 P.M.

Upon seeing this paragraph I wrote a letter, addressed to Dr. Hemphill, inquiring whether the camera was fixed or held in the hand during the exposure, and whether he had himself seen the ball of fire wandering to and fro upon the sea. In reply to which he courteously sent me a silver print from his negative and the following letter:—

"6, Windsor Terrace, Kingstown.

"August 30th, 1893.

"Dear Sir,—In answer to your letter I beg to give you the following particulars. I was sitting in my window opposite the sea, and, anxious to take a photo of lightning, I placed my camera—a small ¼ plate hand camera—on a table; my daughter was sitting with me watching the storm. When I opened the shutter to take the stream of lightning on the left of the picture, my daughter called out—'A ball of fire has fallen near Sandycove!' I at once moved the camera in my hand towards Sandycove, the tower of which you see on the right of the bay. The light from the heavens on sea, land, &c., was almost blinding, otherwise the night was quite dark about 11 o'clock p.m.; but unfortunately, just as I had the plate exposed, a man lit the lamp shown in the picture. I kept the camera pointed in the position of the balls for some seconds, and my daughter tells me that she distinctly saw three balls fall into the sea at short intervals. I examined the negative with a high power pocket glass, and am of opinion that the connecting lines between the balls were caused by reflections from the gas-lamp, which was brilliantly illuminated by the electric discharges, and probably caused the lines during the moving of the camera (still open). I may tell you I showed the negative to Sir Howard Grubb, who examined it with me, and also to Prof. Tichborne. The explanation about the gas-lamp causing the lines was

suggested by Sir H. Grubb, and indeed the true lightning lines are easily distinguished under the magnifying power, as they have a central line with distinct penumbra, which the lamp lines have not. . . .

"Believe me, dear sir, yours faithfully,

"W. D. Hemphill"

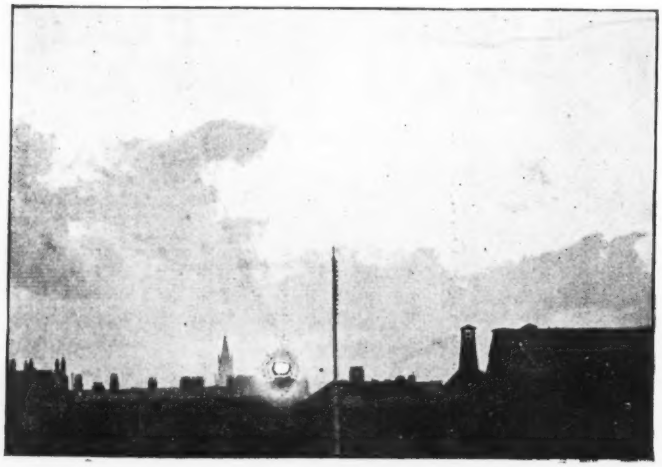

Fig. 2.—Photograph of setting sun taken by Mr. Glover in the month of May, 1893

A close examination of the photograph shows that the bright spots upon the sea are joined by lines which, after following a very irregular course, lead to the gas-lamp. The circular halo round the gas-lamp is evidently caused by reflection of light from the back of the plate, and shows that the flame of the gas must have been very bright. It seems to have been sufficiently bright to trace a line on the sensitive plate as the camera was moved, producing a larger over-exposed patch wherever the camera momentarily stopped. The camera seems to have been stopped and held steady for a considerable time in the position where the image of the lamp is brightest—probably one of the lightning flashes occurred during this interval — but there is a double image of the horizon and of other distant objects which it seems probable were produced at the instant when the landscape was lit up by the two flashes of lightning shown on the left hand of the picture, the camera being pointed in slightly different directions at the instant of each flash.

The circular halo which frequently appears round the photographic image of small bright objects has caused much speculation to observant photographers, and has been a fruitful source of theories with regard to photographic action. Some years ago, when studying eclipse photographs, I made a series of experiments to determine the cause of similar halos which are sometimes seen round the bright images of prominences, and found that the diameter of the halo varied with the thickness of the glass plate on which the photograph is taken. When a brilliant point of light is photographed, and the image is over-exposed, its photographic image is surrounded by a brilliant halo, the inner edge of which is comparatively sharp while the outer edge is very soft and nebulous. On measuring the thickness of the plates used, and the diameter of the circle corresponding to the inner sharp edge of the halo, I found that the inner edge of the halo corresponded to the place where light from the luminous image was reflected at the critical angle from the back of the plate. During the exposure the parts of the photographic film which are being acted upon are brilliantly illuminated, and light must be dispersed from the illuminated parts of the film in all directions within the thickness of the plate. The light which falls nearly perpendicularly upon the back surface of the plate in great part emerges and is lost in the space behind the plate, but a part is reflected, and on reaching the film on the front surface produces, if it is sufficiently intense, a photographic effect. Of the dispersed light which falls more obliquely on the back of the plate, a larger proportion is reflected, but it is distributed over an area which increases with the distance from the illuminated part of the film, so that the intensity of the photographic action of the reflected light on the film at first decreases till the angle of total reflection at the back of the plate is approached, when the intensity of the reflected light rapidly increases.

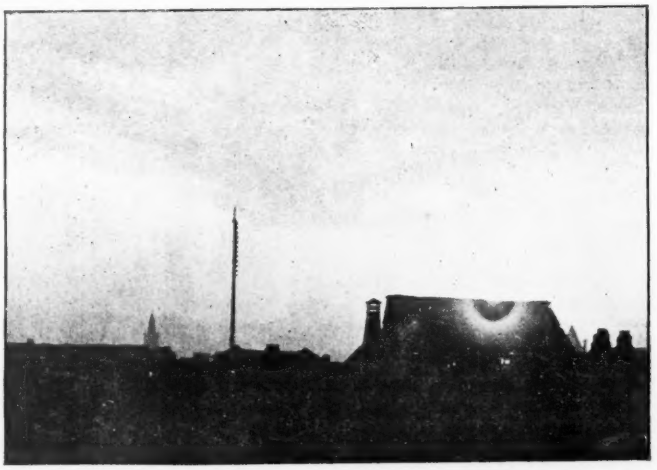

Fig. 3.—Photograph of setting sun taken by Mr. Glover, 13th June, 1893.

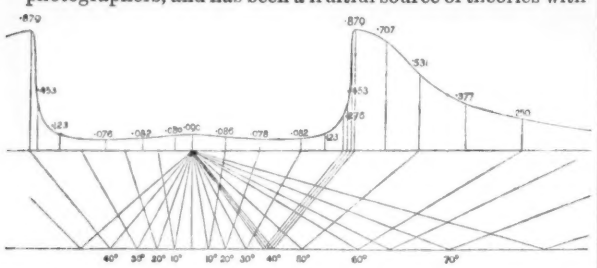

Fig. 4.—Diagram showing the intensity of light reflected from the back of a photographic plate.

In order to further verify this theory, I calculated according to Fresnel's law the intensity of the light which would be reflected from the back of the plate, and would reach the film on the front surface at various distances from the luminous point, on the assumption that the photographic plate was made of crown glass, with an index $\mu = 1{\cdot}54$, and that light would be uniformly dispersed in all directions within the plate from the luminous part of the film during the exposure. Fig. 4 is a curve, the height of which corresponds to the intensity of the light, on the above suppositions, reaching the front surface of the plate after reflection at various angles from the back

surface of the plate. It will be seen that the height of the curve seems to correspond with the intensity of the photographic action, and to confirm the theory with which we set out.* In one total solar eclipse photograph taken during the American eclipse of 1869 there was a curious spot of light upon the dark body of the moon, which was spoken of by one writer as probably due to a comet between us and the moon. It was situated immediately beneath a bright prominence on the sun's limb, and was evidently due to the reflection of the light of the prominence from the inner surface of a drop of water on the back of the plate during the exposure. The wet collodion process was used in those days. Now that dry plates are used, comets on the moon are less likely to be discovered.

Figs. 2 and 3 have been made from photographs kindly sent me by Mr. M. Glover, of Stephen's Green, Dublin. They represent the image of the sun setting over the roofs in the neighbourhood of his studio, and show the ring of light reflected from the back of the photographic plate encroaching upon the dark objects on the horizon. Owing to the size of the sun's disc the inner edge of the nebulous ring is not quite as sharply defined as in the case of nebulous rings about the over-exposed images of stars and artificial points of light.

THE CONSTITUTION OF GASES.

By J. J. Stewart, B.A.Cantab.

(*Continued from page* 55.)

When a solid is raised to such a temperature that it becomes luminous, and the light which it gives out is viewed through a spectroscope, a continuous spectrum is observed which consists of an uninterrupted band of light, and which extends, if the luminous body is hot enough, from the dark red rays at one end to the violet at the other. When a gas, on the other hand, is raised to a high temperature it gives a very different sort of spectrum. This consists of a series of bright lines, or sometimes bands, separated by intervals of darkness, the position of the lines being characteristic of the particular gas. In some cases the luminous bands are very numerous, as in the spectrum of nitrogen; in others the spectrum is of a very simple character, as that of sodium vapour, which, under certain conditions, consists of only two narrow yellow lines close together.

The spectra of hot gases are explained by the vibrations set up in the free gaseous molecules. When the temperature of a gas is raised the velocity of its particles increases, and the encounters between them become more numerous and energetic. After a collision two molecules may be imagined rebounding from each other in a state of vibration due to the shock. The molecules of each gas are capable of vibrating in certain definite modes, which are characteristic of the particular gas, and these vibrations, being communicated to the luminiferous ether, give rise to the definite rays in the spectrum of the gas.

It is a remarkable fact that when the rays from a bright source of light, such as incandescent lime, are made to pass through a layer of cooler gas, the spectrum produced has dark lines occupying the same places as would be filled by the bright lines occurring in the spectrum of the gas in question when heated. The dark lines in the solar spectrum are an example of this, the layer of cooler gas here being found in the region outside the sun's photosphere. The occurrence of these dark lines is due to the absorption by the cold gas of a part of the energy in the luminous waves passing through it. The molecules of the gas are capable of absorbing those vibrations which they are able to give out when they themselves are heated. An analogous phenomenon is the resonance of a musical string. The stretched string can be made to vibrate when the note which it is capable of giving is sounded in its neighbourhood, and a set of such strings can take up from a mixture of notes those vibrations which they themselves would yield, and thus they absorb a portion of the energy of the vibrating air. Even when the layer of gas is sufficiently hot to give out light, the dark lines are seen when the source behind it is hotter than the gas, as the rays given out from the gas, being less intense than the neighbouring rays which are not affected by it and pass through it, appear dark in comparison.

On the fact of the possession by each gas of a characteristic spectrum the methods of spectrum analysis depend. When a compound under investigation can be vaporized, the presence of various elements in it may be detected by observing the position of the lines in the spectrum and comparing these with the known position of the lines in the spectra of the different elements. Such methods are being increasingly used in astronomical investigations, as giving an insight into the constitution of the fixed stars and nebulæ.

The molecules of a gas during the greater part of their course move freely and independently of neighbouring molecules, but in the case of liquids a molecule never gets beyond the influence of its neighbours so long as it remains part of the liquid. The particles of the liquid move with various velocities, and when the liquid has a free surface it may happen that some of the molecules on or near that surface have such a high velocity that they are shot right out of the liquid and move about freely in the space above it. This is what takes place when *evaporation* is going on. When the temperature of the liquid is raised the rapidity of movement of its molecules is increased, and there are a greater number in the surface layer which have a high enough velocity to get outside the sphere of influence of their neighbours—that is, evaporation takes place more rapidly. Amongst the molecules of the vapour thus produced above the liquid, some in the course of their movements approach so near the liquid surface that they become entangled amongst the liquid particles and are re-absorbed into the liquid. This entering and leaving of the molecules is constantly going on at every exposed liquid surface, and evaporation only takes place when the number of molecules which escape from the liquid is greater than that of those which re-enter it. When the number absorbed is in excess, condensation occurs. But even when the mass of the liquid remains unaltered and neither evaporation nor condensation seems to be taking place, this movement of molecules outward and inward is still going on, only now as many molecules re-enter as leave the liquid; what has been called a state of movable equilibrium has been set up.

The solution of a gas in a liquid is a similar phenomenon. When the gas-molecules reach the surface of the liquid, they are retained there, on account of the attraction of the molecules of the liquid on those of the gas. Some of the molecules which have thus entered the liquid, on returning to its surface with a high velocity are able to leave it, and, as before, equilibrium ensues when the number entering and leaving is the same. When the pressure of the gas alters, the number of molecules striking the liquid surface will change in the same proportion, and

* A further account of these experiments will be found in the *Memoirs of the Royal Astronomical Society*, Vol. XLVI., pp. 230—233.

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for equilibrium to be maintained, the number leaving the liquid, and therefore the number of dissolved molecules, must change in this same proportion—*i.e.*, the quantity of gas dissolved is proportional to the pressure, which is known experimentally to be the case.

An interesting example of the behaviour of gaseous molecules is furnished by the radiometer invented by Mr. Crookes. This consists of a set of light fans or vanes made of aluminium, and mounted so as to be able to rotate easily, the whole being enclosed in a globe of glass, in which the air is highly rarefied. One side of each vane is of polished aluminium, the other is covered with lamp-black. When the arrangement is exposed to radiation, the lamp-black surface absorbs more heat, and is thus at a higher temperature than the bright surface of the vane. Therefore, the particles of gas, when they strike the black surface, rebound with a higher velocity, and produce a greater reaction than when they meet the bright and cooler surface. In this way the metal vanes are caused to revolve, the bright polished faces foremost, and when the radiation on them is strong they spin rapidly round. The gas surrounding the vanes must be rarefied, and not at the ordinary pressure, in order that the time when a particle is on its free path may be great compared with that taken up by collisions. The gaseous molecules move backwards and forwards between the glass sides of the globe and the vanes, rebounding at a relatively low velocity from the glass, which is transparent to the rays falling upon it, and is not heated.

In some remarkable experiments in 1822 Cagniard de la Tour heated various liquids, such as alcohol and ether, in strong glass tubes in which the vapour formed was confined within a limited space and was not allowed to occupy more than from two to five times its original volume. Thus the contents of the tube existed under a high pressure, and as the temperature was raised at a certain point the liquid seemed suddenly to become completely changed into vapour.

In an extended series of experiments on carbonic acid gas, Dr. Andrews showed that above a temperature of 30·92° C. no amount of pressure was able to liquefy it. At high pressures above this temperature the substance may be considered to be in an intermediate condition, and to be neither a liquid nor a gas. The temperature above which a gas cannot be liquefied by means of pressure is called the *critical temperature* of the gas.

A gas can continuously be changed into a liquid, without any abrupt alteration in its state, by compressing it while above its critical temperature to the volume it would occupy when liquid; then on lowering the temperature below the critical point, while maintaining the pressure, the substance is found to be in the liquid state.

From these phenomena Dr. Andrews concluded that the liquid and gaseous states are merely widely separated forms of the same condition of matter.

There is a mutual attraction between the molecules of a gas, which acts so as to assist the external pressure to which the gas is exposed. As the volume of the gas decreases, the molecules may come so near together that their attraction towards each other may hold them together or vibrating about a common centre; then the kinetic energy of the molecules will not separate them, and no external pressure is necessary to maintain the volume the same. The gas has become a liquid. When the gas is above the critical temperature, the kinetic energy of the molecules is so great that no diminution of volume will enable the attraction of neighbouring molecules to link them together and so balance the pressure due to the energy of their motion; the gas cannot then be liquefied.

THE EARTH IN SPACE.

By William Schooling, F.R.A.S.

THERE is a curious fascination in putting side by side the myth and science of astronomy. The old legends of the sun and moon, of earth and sky, of heaven and the stars, tell us of the self-same objects whose place and size, whose weight and nature astronomers are chronicling to-day.

The difference is great indeed between the guesses of early times and the methods of modern science; nowhere else, perhaps, is the contrast seen so well between the infancy and the maturity of the mind of man, and no part of astronomy shows it so clearly as that which tells of the earth's place in the universe.

To the Greeks eight centuries before Christ the earth was flat, surrounded by the sea, and covered by the canopy of sky, which is the floor of heaven, the abode of the Olympian gods.

Greece was at the centre of the earth, and Delphi at the central point of Greece, for Jupiter sent forth two eagles from the east and west that met upon the spot where stood the Delphian temple, thus proved to be the centre of the world. The sun and stars climb up the crystal dome of sky, and daily descend again through the water into the shadow land beneath—the realm of forgetfulness and the region of death. The Ethiopians in the east and west were closer to the sun than were the Greeks, and by its nearness, as it rose and set, the Ethiopians were scorched.

The sun plunged in the ocean as it set, and the Greeks record the hissing heard by the Iberians at sunset when the burning sun fell into the sea. Tacitus tells the same story of our northern ancestors, and in Polynesia the notion lingers still that the natives of the western isles have heard the hissing of the sunset; while in Peru, the legend was that the sun rushed to the sea and by its heat dried up the greater part, then dived below the earth that was upon the water, and daily rose again by the gateways of the east.

These seem curious fancies to us who have learnt that the volume of the sun is more than a million times greater than the earth; who know that though the ocean stretches for thousands of miles, yet the sun is so remote that while a flash of light could pass more than seven times round the earth in a single second, it would take eight minutes to reach us from the sun; who know also that if, not once a day, but once a minute for fifteen centuries, the whole sea could be poured into an abyss the size of the sun, it would not fill it up. Yet the thought is natural that the ocean stretches so far that the sun must fall into it when it sets, and is so vast that it can easily contain the sun. Had we no teachers to tell us of their own or other men's discoveries, there are not many of ourselves but would be satisfied with thinking of things as they appear at first sight to be, and the heavens would appear to us, as to others, near at hand, and readily accessible. To us, as to the Greeks, the rainbow would stretch down from heaven a sign of war and tempest, or the pathway of a messenger from gods to men; just as to the South Sea Islander it is the heaven-ladder that the heroes climb. To the Scandinavians it was Bifröst, the trembling bridge, timbered of three hues, and stretched from sky to earth. In German folk-lore the souls of the just are led by guardian angels along the rainbow into paradise, and it is the bridge of souls with Arabs and Chinese.

But not alone by the rainbow do we pass to heaven: a legend from Samoa tells of a mountain reaching to the sky, and of a tree that when it fell was sixty miles in length,

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but up which men used to climb; and everywhere we come across legends of trees rooted in the earth with branches reaching to the sky, or of trees rooted in the sky with branches stretching downwards to the earth.

In the sky are land and sea, with people, houses and plantations, but most often it is the dwelling-place of heroes and deities alone.

In Paraguay the souls of the dead go up to heaven by the tree *Llagdigua*, which joins the earth and sky, and there are myths that tell of a rope let down to earth whereby intercourse is kept up with the sky. Such a story is told in Vancouver's Island; and in the White Nile district it is said that God made all men good and they lived with Him in heaven, but as some of them turned bad He let them down by a rope to the earth. The good could climb up again by this rope to the sky, where there was dancing and beer and all was joyous, but the rope broke (or a bird bit it through), so there is no going up to heaven now; it is closed to men.

But if we turn to science, how different is the story that we have to tell! It is like the old myths of heaven-raising that tell how once the sky fell down so low that men could not stand upright, and then a hero came, who, for a drink of water, raised the sky and pushed it up and up to the place where we see it now.

For us science is the hero who has raised the heaven, that has examined far-off worlds, that has explored the sky depths, and has stories to tell more marvellous and more romantic than the myths of old.

It has to tell us that the earth is far larger than men used to think, though the true size of the earth has been approximately known for centuries, and yet it has to tell us also that the place of the earth in space and time is one of inconceivable insignificance. But first think of the greatness of our world. It is a globe nearly eight thousand miles in diameter, but only by putting figures into other shapes and forms do we begin to see their meaning.

This globe contains two hundred and sixty thousand million cubic miles, and could we load a train with it the length of the train (if the inside of the trucks were six feet wide and six feet high) would be over two hundred thousand billion miles, and travelling at the rate of sixty miles an hour it would take over three thousand eight hundred and thirty-eight million centuries to pass a given point, while if the engine-driver could communicate with the rear-guard by means of flashes of light it would be thirty-four thousand years before the guard saw the signal; while if we form the earth into a square column reaching to the sun, a distance of ninety-three million miles, each side of the column would be over fifty miles in length. Yet vast as these figures seem, they fade into insignificance by comparison with the sun, for if *it* were formed into a square column reaching to the earth each side of the column would measure sixty thousand miles, or eleven hundred times as much as the earth column; put in other words, the sun would provide one million three hundred thousand such columns as the earth would make.*

Even if we keep within the limits of our solar system, we have distances much more vast than that from sun to earth.

If we stretch our columns until they reach from the sun to Jupiter, the earth-column shrinks to twenty-three miles square, the sun-column to twenty-six and a half thousand; while reaching out to Neptune, the most distant of the planets, the column formed by the earth would be less than ten miles square and the sun eleven thousand, while their length has grown to twenty-eight million centuries of miles.

How curious a contrast even this affords to more primitive conceptions of the sky, such as that of the Samoans, who think the heavens are at the horizon, or that strangers that come to them, as the white men did, come from beyond the sky and are therefore *Papalangi*, or heaven-bursters.

The heaven for them has windows or holes where the rain comes through, and if you climb high enough you can look through and see the sky folk living much as men do on the earth. And the Waraus say that there was once a rope by which people used to climb down to the earth through a hole in the sky, until one day a fat man stuck in the hole and people now can neither get up nor down.

Of men beyond the arch of heaven science knows nothing, but it can say something in regard to the possibility or otherwise of life such as we know it here on other planets, because it can tell something of their temperature, atmosphere and other conditions; but as to life in other suns or stars, science for the most part has no word to say and leaves us to guess, like Samoans and more primitive folk.

As to other worlds scattered through the sky depths, science has lately been learning much; something of their nature, their number, their distance is constantly being learnt, while the way is being prepared for gaining some real insight into the relations of the stars among themselves, and for fixing our own position in regard to other suns and systems than our own.

To Epicurus the stars were little concave mirrors fixed in the firmament and reflecting sunlight; to the Venerable Bede they were faintly luminous, needing reinforcement from the sun to make them visible. Even to Tycho Brahe there was no great distance between the planets and the stars, and he calculates their distance at fifty to sixty thousand miles.

But we have to invent a new measure for talking of their distance, since, finding miles too small, we talk of "light years," which means the distance that a ray of light travelling some hundred and eighty-six thousand miles a second would traverse in a year.

Before we get too used to talking of light years it may be well to try to get a notion what a light year really is. It means a journey that would take an express train more than eleven million years. It means a velocity that the periphery of a gigantic fly-wheel one hundred miles in diameter could not keep up with, though it made five hundred revolutions in a second. It means a distance traversed in one second that sound will not pass over in ten days.

And this is the unit for the quantities that modern astronomy deals with when treating of the distribution of stars in space. Sometimes one hears a cubic light year spoken of—that is, an imaginary cube with each side a light year long.

It was long after men saw how to measure the distance of the stars before they succeeded so as to feel much confidence in the results obtained; but now the distances of a few stars are known with comparative accuracy and certainty, many measures having been made that probably come within twenty or thirty per cent. of the truth.

The nearest star that has been found is Alpha Centauri, with a distance of $4\frac{1}{3}$ light years. Probably next in order is a small star, numbered 21,185 in Lalande's catalogue. It is about $6\frac{1}{2}$ light years off, while 61 Cygni, the most

* The earth is about four times as dense as the sun, and if the columns of matter were of the same density the sun would only make three hundred and thirty-two thousand columns such as the earth would make.

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frequently measured of any star, is about 7 to 7½ light years off. But let us take our nearest neighbour and try to see something of the isolation of our solar system in space. Let us try to conceive of a sphere of which the sun is centre with a radius of 4·35 light years, so placing our nearest stellar neighbour on its circumference—translated into the more familiar unit its diameter is over fifty billion miles and its cubic contents nearly three hundred and fifty cubic light years, or seventy thousand sextillions (7 with 40 ciphers) of cubic miles, for a cubic light year is rather more than two hundred sextillions cubic miles. Here is isolation indeed! The sun, with all its vastness, does not fill one two hundred thousand trillionth (2 with 23 ciphers) part of the sphere that has our nearest stellar neighbour on its surface; the gigantic volume of the sun in such a space is like an isolated shot containing but one half of a cubic inch immersed in the whole water of the sea,* while a little speck less than the two millionth of a cubic inch suspended in the three hundred and seventy-three trillion gallons of the sea would represent the earth suspended in the sphere, the radius of which reaches only to the nearest star.

Did we set the Pole star at the limits of our space sphere, the volume of the sphere would be three thousand times as great; and the sun must be thought of as occupying the six thousandth part of an inch in the four hundred million cubic miles of sea.

Were Vega, at a distance of ninety-six light years, on the boundary of our sphere, the space that reaches to our nearest neighbour must be increased ten thousand times in volume, and the earth becomes a difficult microscopic object in the vast abyss of sea. These are all stars whose distance has been measured with more or less accuracy, but there are other objects more remote that have defied all attempts to measure them—in literal fact, they are *immeasurably* remote distances.

Whether we are to reckon the number of their light years by centuries only, by thousands or by millions, it is premature to guess. One thing at least is clear; the figures given here to show the position of the earth in space are wholly paltry and inadequate compared with the (as yet) unknown reality. Much has been learnt and the way prepared for yet greater advances. Man has dethroned himself from the chief position in the universe; has seen his world cease to be the centre round which all else revolves; has recognized his abode as the tiniest imaginable speck in space; man—

> "Who sounds with a tiny plummet, who scans with a purblind eye,
> The depths of that fathomless ocean, the wastes of that limitless sky"

—yet has a longing to penetrate still farther through the star depths to win yet other secrets from the mysteries of space.

Though thus enlarging his horizon, he sees the earth sink into insignificance more and more, yet relatively to himself it becomes more important; it is part of a larger whole, and it must supply him with the key to unlock the secrets of the universe elsewhere. It is the starting-point for the survey that has revealed so much, that will reveal still more, but ever as the boundary of the known extends, it is encompassed by an unknown that is extended too. However vast in space or time the knowable becomes, the unknowable is vaster still; the man whose horizon is widest, whose knowledge is most profound, knows best and feels most reverently that, however much we learn, there remains a mystery beyond, surrounding all.

* I have shown, in an article published in *Longman's Magazine* for June, 1893, that all the water of the sea, collected into a sphere, would fill a space about nine hundred miles in diameter.

THE FACE OF THE SKY FOR OCTOBER.

By Herbert Sadler, F.R.A.S.

At the time of writing, a very fine group of spots is visible on the Sun. There is an annular eclipse of the Sun on the 9th, but it is invisible at Greenwich, and the path of the annulus lies almost wholly across the Pacific Ocean; it therefore needs no further notice. Conveniently observable minima of Algol occur at 10h. 23m. P.M. on the 16th, and 7h. 12m. P.M. on the 19th.

Mercury is too near the Sun during the month to be visible. Venus is an evening star, but, owing to her great southern declination, is very badly situated for observation. On the 1st she sets at 6h. 44m. P.M., or 1h. 4m. after the Sun, with a southern declination of 18° 5′, and an apparent diameter of 14½″, about ⅔ths of the disc being illuminated. On the 15th she sets at 6h. 27m. P.M., or 1h. 22m. after the Sun, with a southern declination of 22° 47′, and an apparent diameter of 16″, $\frac{71}{100}$ths of the disc being illuminated. On the 31st she sets at 6h. 23m. P.M., or 1h. 49m. after the Sun, with a southern declination of 25° 49′, and an apparent diameter of 17½″, $\frac{86}{100}$ths of the disc being illuminated. During the month she passes from Libra through Scorpio into Ophiuchus, being very near δ Scorpii on the evening of the 12th.

Mars is, for the purposes of the amateur observer, invisible.

Jupiter is an evening star, and is admirably situated for observation. He rises on the 1st at 7h. 24m. P.M., or 1h. 44m. after sunset, with a northern declination of 19° 20′, and an apparent equatorial diameter of 45″. On the 15th he rises at 6h. 26m. P.M., or 1h. 21m. after sunset, with a northern declination of 19° 8′, and an apparent equatorial diameter of 46½″. On the 31st he rises at 5h. 20m. P.M., or three-quarters of an hour after sunset, with a northern declination of 18° 47′, and an apparent equatorial diameter of 48″. During the month he describes a short retrograde path in Taurus, to the south-west of the Pleiades. The following phenomena of the satellites occur while the planet is more than 8° above and the Sun 8° below the horizon:—On the 1st a transit egress of the first satellite at 3h. 53m. P.M. On the 4th a transit ingress of the shadow of the second satellite at 10h. 4m. P.M. On the 5th a transit ingress of the first satellite at 0h. 9m. A.M.; a transit egress of the shadow of the satellite at 0h. 24m. A.M.; and a transit egress of the satellite itself at 2h. 24m. A.M. On the 6th an eclipse disappearance of the third satellite at 1h. 7m. 15s. A.M.; its reappearance at 2h. 36m. 48s. A.M.; an eclipse disappearance of the first satellite at 3h. 43m. 50s. A.M.; an occultation disappearance of the third satellite at 5h. 20m. A.M.; an occultation reappearance of the second satellite at 9h. 26m. P.M. On the 7th a transit ingress of the shadow of the first satellite at 1h. 2m. A.M.; a transit ingress of the satellite itself at 2h. 2m. A.M.; a transit egress of its shadow at 3h. 14m. A.M., and of the satellite itself at 4h. 13m. A.M.; an eclipse disappearance of the first satellite at 10h. 12m. 20s. P.M. On the 8th an occultation reappearance of the first satellite at 1h. 20m. P.M.; a transit ingress of the first satellite at 8h. 28m. P.M.; a transit egress of its shadow at 9h. 42m. P.M., and a transit egress of the satellite at 10h. 39m. P.M. On the 9th a transit egress of the third satellite at 8h. 30m. P.M. On the 12th a transit ingress of the shadow of the second satellite at 0h. 40m. A.M.; a transit ingress of the satellite itself at 2h. 30m. A.M.; a transit egress of its shadow at 3h. 0m. A.M., and of the satellite at 4h. 45m. A.M. On the 13th an eclipse disappearance of the third satellite at 5h. 7m. 10s. A.M.; an eclipse disappearance of the second

satellite at 7h. 47m. 58s. P.M.; an occultation reappearance of the second satellite at 11h. 45m. P.M. On the 14th a transit ingress of the shadow of the first satellite at 2h. 56m. A.M.; a transit ingress of the satellite itself at 3h. 48m. A.M.; a transit egress of the shadow at 5h. 8m. A.M. On the 15th an eclipse disappearance of the first satellite at 0h. 6m. 37s. A.M.; its reappearance from occultation at 3h. 6m. A.M.; a transit ingress of the shadow of the first satellite at 9h. 24m. P.M.; of the satellite itself at 10h. 14m. P.M.; a transit egress of its shadow at 11h. 36m. P.M. On the 16th a transit egress of the first satellite at 0h. 25m. A.M.; a transit egress of the shadow of the third satellite at 8h. 59m. P.M.; an occultation reappearance of the first satellite at 9h. 33m. P.M.; a transit ingress of the third satellite at 10h. 45m. P.M., and its egress at 11h. 57m. P.M. On the 19th a transit ingress of the shadow of the second satellite at 3h. 17m. A.M.; a transit ingress of the satellite itself at 4h. 49m. A.M.; a transit egress of its shadow at 5h. 37m. A.M. On the 20th an eclipse disappearance of the second satellite at 10h. 23m. 3s. P.M. On the 21st an occultation reappearance of the second satellite at 2h. 2m. A.M.; a transit ingress of the shadow of the first satellite at 4h. 50m. A.M., and of the satellite itself at 5h. 33m. A.M. On the 22nd an eclipse disappearance of the first satellite at 2h. 1m. 1s. A.M., and its reappearance from occultation at 4h. 52m. A.M.; a transit egress of the second satellite at 8h. 13m. P.M.; a transit ingress of the shadow of the first satellite at 11h. 18m. P.M., and of the satellite itself at 11h. 59m. P.M. On the 23rd a transit egress of the shadow of the first satellite at 1h. 30m. A.M.; a transit egress of the satellite itself at 2h. 10m. A.M.; an eclipse disappearance of the first satellite at 8h. 29m. 46s. P.M.; a transit ingress of the shadow of the third satellite at 11h. 14m. P.M.; an occultation reappearance of the first satellite at 11h. 18m. A.M. On the 24th a transit egress of the shadow of the third satellite at 1h. 0m. A.M.; a transit ingress of the satellite itself at 2h. 8m. A.M., and its transit egress at 3h. 19m. A.M. On the 25th a transit egress of the shadow of the first satellite at 7h. 59m. P.M., and of the satellite itself at 8h. 36m. P.M. On the 26th a transit ingress of the shadow of the second satellite at 5h. 53m. A.M. On the 28th an eclipse disappearance of the second satellite at 0h. 58m. 6s. A.M.; an occultation reappearance of the second satellite at 4h. 18m. A.M. On the 29th an eclipse disappearance of the first satellite at 3h. 55m. 32s. P.M.; a transit ingress of the shadow of the second satellite at 7h. 12m. P.M.; of the satellite itself at 8h. 16m. P.M.; a transit egress of the shadow at 9h. 33m. P.M., and of the satellite itself at 10h. 30m. P.M. On the 30th a transit ingress of the shadow of the first satellite at 1h. 12m. A.M.; of the satellite itself at 1h. 43m. A.M.; a transit egress of the shadow at 3h. 25m. A.M., and of the satellite at 3h. 54m. A.M.; an eclipse disappearance of the first satellite at 10h. 24m. 15s. P.M. On the 31st an occultation reappearance of the first satellite at 1h. 2m. A.M.; a transit ingress of the shadow of the third satellite at 3h. 14m. A.M., and its egress at 5h. 1m. A.M.; a transit ingress of the satellite itself at 5h. 27m. A.M.; a transit ingress of the shadow of the first satellite at 7h. 41m. P.M.; of the satellite itself at 8h. 9m. P.M.; a transit egress of the shadow at 9h. 53m. P.M., and of the satellite itself at 10h. 20m. P.M. The following are the times of superior and inferior geocentric conjunctions of the fourth satellite with the centre of the planet:—Superior, October 5th, 6h. 18½m. P.M., October 22nd, 9h. 23m. A.M.; Inferior, October 14th, 3h. 13m. A.M., October 30th, 5h. 52·5m. P.M.

Saturn is in conjunction with the Sun on the 8th, and Uranus is invisible.

Neptune is well situated for observation, rising on the 1st at 8h. 8m. P.M., with a northern declination of 20° 54′, and an apparent diameter of 2·6″. On the 31st he rises at 6h. 6m. P.M., with a northern declination of 20° 50′. During the month he describes a short retrograde path in Taurus, in a region barren of conspicuous stars.

October is a fairly favourable month for shooting stars, the most marked display being that of the Orionids on the 18th, the radiant point being in vi.h. 8m. R.A., and 15° northern declination.

The Moon enters her last quarter at 3h. 19m. P.M. on the 2nd; is new at 8h. 27m. P.M. on the 9th; enters her first quarter at 11h. 20m. P.M. on the 17th; is full at 7h. 28m. A.M. on the 25th; and enters her last quarter at 10h. 42m. P.M. on the 31st. She is in apogee at 10h. A.M. on the 15th (distance from the earth 251,626 miles); and in perigee at 7h. A.M. on the 27th (distance from the earth 225,040 miles).

Chess Column.

By C. D. Locock, B.A.Oxon.

All communications for this column should be addressed to the "Chess Editor, *Knowledge Office*," and posted before the 12th of each month.

Solution of September Problem (C. D. Locock):—

1. R to R4, and mates next move.

Correct Solutions received from Alpha, H. S. Brandreth, Poppy, R. B. Cooke, and F. Glanville.

Additional Solutions of August Problem received from Alpha and H. S. Brandreth.

Alpha.—Your original letter containing the above must have miscarried.

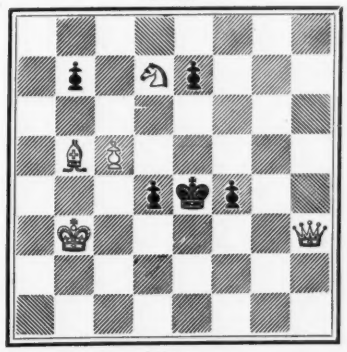
Poppy.—The Problem ("Sweetness, &c.") arrived safely.

W. A. Champion.—The move 1. R to B3 in the September Problem is what is technically known as a good "try." As you rightly observe, there is no mate if Black replies 1. . . . Kt to K2. R to B3 cannot, therefore, be the correct key; you will find the latter given above.

PROBLEM.

By G. K. Ansell.

Black.



White.

White to play and mate in two moves.

"Knowledge" Three-move Problem Tourney.

The Chess-Monthly, Nuova Rivista degli Scacchi, British Chess Magazine, Hackney Mercury, Southern Counties' Chess Journal, &c., are thanked for notices of this Tourney,

entries for which close on October 10th. The full conditions will be found in the August and September numbers of Knowledge, and may be had on application to the Chess Editor.

Solution Tourney.

1st Prize.—Half-a-guinea.
2nd Prize.—Bird's *Chess History and Reminiscences.*

This will commence in the November number, and will run concurrently with the Problem Tourney.

Two or three Problems will be published each month.

Solutions must reach Knowledge Office on or before the 12th of each month.

Marks will be awarded as follows:—For each correct key-move, three points; for each dual continuation (on the second move), one point. One point will be *deducted* for every incorrect claim. If a Problem has no solution, "No solution" must be claimed. If a Problem has more than one solution, duals will not score.

The following game was recently played at Simpson's Divan:—

Ruy Lopez.

White (H. E. Bird).	Black (Van Vliet and Schwann).
1. P to K4	1. P to K4
2. KKt to B3	2. QKt to B3
3. B to Kt5	3. P to Q3
4. P to QB3 (*a*)	4. P to KB4
5. P to Q4	5. P × KP
6. Kt × P (*b*)	6. P × Kt
7. Q to R5ch	7. K to K2
8. B to Kt5ch	8. Kt to B3
9. B × QKt	9. P × B
10. P × P	10. Q to Q4
11. B to R4	11. B to R3! (*c*)
12. P to QB4 (*d*)	12. Q to R4ch!
13. Kt to B3? (*e*)	13. K to K3!
14. B × Kt (*f*)	14. P × B
15. Q to R3ch	15. P to B4
16. Castles (KR)	16. B × P
17. KR to Ksq	17. B to Q6
18. Kt × P	18. B × Kt
19. R × B	19. Q to Q4 (*g*)
20. QR to Ksq (*h*)	20. B to Kt2
21. KR to K3?	21. QR to Qsq
22. R to KB3	22. Q to K5!
23. R to QBsq? (*i*)	23. Q to B7
24. R to KBsq	24. R to Q8
25. P to KKt4	25. R × Rch
26. K × R	26. Q to B5ch
Resigns.	

Notes.

(*a*) Steinitz was the first to discover and condemn this move on account of Black's reply.

(*b*) With very bad judgment White enters on a counter attack, which originally occurred in the Steinitz-Blackburne match. Mr. Bird, who must have been well acquainted with the whole variation, fails to perceive that, though a move ahead as compared to the game referred to, this circumstance is actually a disadvantage—*vide* note (*c*).

(*c*) Better now than 11. . . K to K3 as played by Steinitz, because White, owing to his 4th move, cannot attack the Queen with Knight.

(*d*) In order to bring out the Knight at B3. 12. P × Ktch, followed by the exchange of Queens, would leave Black a great superiority, while 12. Kt to Q2, K to K3 would leave Black a piece ahead.

(*e*) A blunder. The *Nuova Rivista*, from which the score of this game is taken, gives the following continuation:—13. P to QKt4, Q × Pch; 14. Kt to Q2, R to Qsq; 15. P × Ktch, P × P; 16. Castles (!). But 16. B × Pch instead would win the exchange, showing that Black's 14th move was incorrect.

(*f*) If the Queen moves, Black takes the KP with Queen.

(*g*) 19. . . R to Qsq seems even stronger.

(*h*) An attempt to draw by 20. R to B4, Q × KP; 21. R × P, Q × R; 22. R to Ksqch, proves futile. His next move is waste of time, but there is no chance anyhow.

(*i*) 23. R to KBsq at once was clearly better. But the Black allies never gave Mr. Bird a chance after his 13th move.

CHESS INTELLIGENCE.

The great Columbian Chess Congress appears after all to have been indefinitely postponed owing to lack of the necessary funds. Several European players had already crossed the Atlantic in order to take part in the tournament when the announcement was made.

Mr. Lasker has at length definitely challenged Mr. Steinitz to a match of ten games up. The other conditions proposed are of a kind with which Mr. Steinitz will not be able to find fault, being in fact those on which he ordinarily insists. The match, if it takes place, is to commence before January 1st, a date which would allow Mr. Steinitz ample time to collect his backers.

Herr Albin, the solitary conqueror of Dr. Tarrasch in the Dresden Tourney, has taken advantage of his visit to the States to play a match with Mr. A. B. Hodges. After each player had won four games the prize was divided.

The National Tournament of the German Chess Association took place at Kiel last month, the result being a victory for Herr Walbrodt. Herr von Bardeleben was second, a great improvement on his recent form, and Herr von Gottschall third.

A very fine series of three-move problems by Mr. Blackburne is now appearing in the weekly chess column of the *Daily News*. Mr. Blackburne adheres to the old school of problem-composition; in other words, each problem has a fine key leading to one main idea, the minor variations (if any) being strictly subordinate. Personally, we much prefer this to the modern style of problem, in which the Black King is chased over the whole board, "a foiled circuitous wanderer."

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